ORIGINAL PAPER

High Maternal Body Mass Index is associated with an Early-Onset of Overweight/Obesity in Pre-School-Aged Children in Malawi. A Multilevel Analysis of the 2015-16 Malawi Demographic and Health Survey

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ABSTRACT

Background: We examined whether individual and community-level maternal nutritional status are associated with an early-onset of overweight/obesity in pre-school-aged children in Malawi.

Design: Data was obtained from the 2015-16 Malawi Demographic and Health Survey (MDHS). The maternal nutritional status measured as body mass index (BMI) and childhood overweight/obesity were assessed using the World Health Organization (WHO) recommendations. To examine whether the maternal high BMI is associated with overweight/obesity in pre-school-aged children, two-level generalized linear mixed models with the logit-link function and binomial distribution models were constructed on 4,023 preschool children dwelling in 850 different communities.

Results: The multilevel regression showed children born to overweight/obese mothers had increased odds of being overweight/obese (adjusted odds ratio [aOR] = 3.11; 95% Confidence Interval [CI]: 1.13–8.54). On the community level children born to mothers from the middle (aOR: 1.68; 95% CI: 1.02–2.78) and high (aOR: 1.69; 95% CI: 1.00–2.90) percentage of overweight/obese women had increased odds of being overweight/obese. Additionally, there were significant variations in the odds of childhood overweight/obesity in the communities.

Conclusions: strategies aimed at reducing childhood overweight/obesity in Malawi should not only address women and their children but also their communities. Proper choices of nutrition, diet, and physical activity patterns should be emphasized on overweight/obese women of childbearing age throughout pregnancy and beyond.

KEYWORDS: overweight; obesity; body mass index; multilevel analysis; Malawi

BACKGROUND

Globally, childhood overweight/obesity is one of the most serious public health hazards, however, its effects are more pervasive in many low- and middle-income countries, particularly in urban settings [1–5]. The number of overweight/obese of children below the age of five was estimated to be over 41 million worldwide and approximately 50 percent of all overweight/obese pre-school-aged children resided in Asia and one-fourth in Africa [3, 4]. Overweight/obese children are more likely to remain in that state even during their adulthood and more likely to develop non-communicable diseases (NCDs) [2, 4–6].

In addition to the interactions between genetic, environmental, and behavioral factors that end disrupting the balance between energy intake and expenditure, social and cultural factors also seem to play an essential role in influencing the closest behavioral patterns that give rise to childhood overweight/obesity [5–8]. Researchers have demonstrated that maternal factors such as socioeconomic position (i.e. education, household wealth and occupation), marital status, and women's smoking during the pregnancy appears to have influences on childhood overweight and obesity [9–12]. Additionally, sex of the child, birth weight, body mass index (BMI) of parents, [9–12] some nutritional factors such as early introduction of solid foods and fruits [12, 13] and Urbanicity [14, 15] have also been implicated in childhood overweight and obesity. Maternal overweight and obesity are intricately linked to adverse health outcomes for the mother and her children [16, 17]. Research has also indicated that children born to overweight/obese mothers are at increased risk of congenital abnormalities, macrosomia as well as overweight and obesity later in life [2, 17].

In Malawi, most nutrition efforts have been concentrated on under-nutrition in pre-school-aged children. However, childhood overweight and obesity have received no attention. The prevalence of childhood overweight has dropped slightly from 9% in 1992 to 5% in 2015 indicating that childhood overweight and obesity have been persistently high over the past two decades [18]. While previous studies [14–17] have shown the independent individual effects on childhood overweight/obesity, the contextual effects have rarely been explored. It has been demonstrated that the community shapes individual opportunities as well as exposes individuals to numerous health risks and resources over their life course [19]. Thus, we aimed to investigate whether the individual and contextual women's nutritional factors will be associated with an early-onset of overweight/obesity in pre-school-aged children.

MATERIALS AND METHODS

The study data, sampling, and design

This study utilized cross section data which were collected in the 2015-16 Malawi Demographic and Health Survey (MDHS) from October 2015 to February 2016. Comprehensive information on the survey sampling techniques and data collection procedures have been described in details elsewhere [18, 20]. Briefly, the 2015-16 MDHS employed two-staged probability sampling and produced a nationally representative sample. Firstly, 850 standard enumeration areas (SEAs) were selected with probability proportional to the size. Households comprised the second stage of sampling. A total of 26,361 households successfully got interviewed representing a 99.2% response rate. To limit the clustering effects that result from sampling more than one child from mothers, a random procedure was employed to select one child per household. We generated a sample size of 4,023 pre-school-aged children.

Survey and data collection

Data were collected from women of childbearing age using face-to-face interviews. Weight measurements of pre-school-age children were measured using the lightweight UNICEF SECA mother-infant scales [21] while the measuring board produced by Shorr Productions were used to obtain the height measurements [18]. The nutritional status of children was calculated using the new WHO growth standards [22]. Women's anthropometric measurements were collected and used to calculate mother's BMI. Height measurements were obtained using standardized measuring boards with accuracy to 0.1 cm while weight measurements were collected using solar-powered scales with an accuracy of 0.1 kg.

MEASURES

Outcome variables

We defined childhood overweight/obesity as children with weight-for-height Z-score greater than 2 standard deviations above the WHO Child Growth Standards median [22].

Main independent variables

Mother's nutritional status (defined at individual and community levels) was measured by the BMI. BMI is defined as a person's weight in kilograms divided by the square of their height in meters (kg/m^2). Using the WHO reference standards, mothers with a BMI of <18.5 kg/m^2 were considered being underweight, those with 18.5~24.9 kg/m^2 normal and ≥ 25 5 kg/m^2 overweight/obese [23]. At community level maternal high nutritional status was defined as the proportion of women in the community categorized as being overweight/obese (≥ 25 5 kg/m^2).

Individual/child/maternal/household-level factors

Child's age (0–12 months, 12–23 months, 24–35 months, 36–47 months, and 48–59 months), Child's sex (male or female), the size of a child at birth (very small/smaller than average, average, and large/larger than average), and the preceding birth interval in months (<24, 24–47, and ≥ 48), maternal age in years (15–24, 25–34, 35–49), highest educational level (no formal education, primary, secondary education and above), and household wealth status (poorest, poorer, middle, richer, and richest). Generated with a statistical procedure known as principal component analysis, the wealth index was constructed using data on a household's ownership of selected assets, such as televisions, materials used for constructing the house and types of water access and sanitation facilities [18, 24].

Community/contextual/area-level factors.

A community was defined based on the sharing of the common primary sampling unit within the MDHS data [20]. Place of residence (urban and rural) and geographical region (northern, central and southern) indicated an area of residence. Two continuous variables assessed, community wealth and community female education. Community female education was defined as the proportion of women aged 15–49 years in the community with primary and above education whereas community wealth was defined as the proportion of households in the community categorized as rich (upper 40% of quintiles). All continuous community-level characteristics were categorized as "low", "medium" and "high" to permit for nonlinear effects and provide results that are more readily interpretable in the development of public health programs and policies.

Statistical analyses

The descriptive statistics [mean, SD and frequencies] were calculated for all variables. Two-level multilevel logistic regression fitting four different models were conducted using generalized linear mixed models (GLMMs) with the logit-link function and binomial distribution to simultaneously analyze the associations of the individual- and community-level factors with childhood overweight/obesity. We presented results of the final models only.

Fixed effects were reported as adjusted odds ratios (aOR) with their p-values and 95% confidence interval 95% (CI). Random effects were expressed in terms of Area Variance (AV), Median Odds Ratio (MOR), Intra-Cluster Correlation (ICC) and Proportion Change in Variance (PCV). The fitness of the models were assessed using Deviance Information Criterion (DIC). Two-tailed Wald test at significance level of alpha equal to 5% was used to determine the statistical significance of the factors. The variance inflation factor (VIF) and Tolerance were used for assessing multicollinearity and no multicollinearity was observed (S1). All data analyses were performed using SAS statistical software version 9.4 (SAS Institute Inc., NC) [25].

Ethics statement

All participants gave informed consent at the beginning of each interview. The Malawi Health Sciences Research Committee, the Institutional Review Board of ICF Macro, and the Centers for Disease Control (CDC) in Atlanta reviewed and approved the protocol for the survey. The authors sought permission from the DHS program for the use of the data.

RESULTS

Sample characteristics

Table 1, 2 and 3 show the descriptive statistics of the study sample. About 22% of mothers were overweight and obese. The prevalence of childhood overweight/obesity was observed to be highest, among children born to mothers with BMI $\geq$ 25 kg/m^2 and from communities with a proportion of overweight/obese women. The prevalence was also highest in male children, children less than 12 months and in children whose birth interval were 48 months and above.

Figure 1 shows the distribution of weight/height z-score in children as well as mothers BMI. Figure 2 and Table 4 shows the scatter plots and correlation between children's weight/height z-score and a selected subset of variables. An increase in maternal BMI, a proportion of women in the community categorized as being overweight/obese, and preceding birth interval were positively associated with an increase in weight/height z-score whilst an increase in child's age was negatively associated with weight/height z-scores.

Random effects

The GLMM results presented in table 5. In Model 4, According to the area variance (AV), the variation remained statistically significant even after adjusting for the individual- and community-level factors [AV = 0.9174; SE = 0.4624] simultaneously. The PCV showed that 1% of the contextual-level variance can be explained by the individual and community-level factors compositional characteristics. Additionally, the MOR showed that the odds of childhood overweight/obese increased

by 49% when mothers moved from low to neighborhoods with a high percentage of women with high BMI. However, ICC shows that about 22% of the total variance remained unexplained even after adjustments for confounders.

Fixed effects

Children born to overweight/obese mothers had increased odds of being overweight/obese (aOR: 3.11; 95% CI: 1.13–8.54). On the community level, children born to mothers from the middle (aOR: 1.68; 95% CI: 1.02–2.78) and high (aOR: 1.69; 95% CI: 1.00–2.90) percentage of overweight/obese women had increased odds of being overweight/obese (Model 4).

DISCUSSION

Our findings show evidence of clustering effects of childhood overweight/obesity at community level suggesting that children in the same neighborhood are exposed to common contextual influences. We found that children born to women with high BMI categories had increased odds of being overweight/obese.

Pre-pregnancy BMI was not available in our dataset, therefore we anticipated that maternal BMI categories at the time of the survey would be the same as that before the index birth. The assumption was made based on what previous research has reported on women who are already overweight/obese having the tendency to retain more weight even after the pregnancy [26, 27]. Studies have reported that for the neonatal, the strongest predictor of obesity later in later in life is preconception BMI [28, 29]. Therefore, the women's preconception weight profile could be an indicator of socioeconomic, environmental and genetic detrimental conditions for the preschool children [30, 26]. Consequently, the risk of childhood overweight/obesity can be influenced by the genetic traits of the family as well as environmental factors [31, 32]. It is well-established that relatively common obesity susceptibility gene variants interact with diet in three probable ways: 1) by increasing the consumption of saturated fat and refined carbohydrate; 2) altering the lipid metabolism regulation pathway, or 3) reduction in energy expenditure [30, 33–35].

Excess weight gain in during the pregnancy has been reported to be associated with a number of poor health and pregnancy outcomes [36–38]. Prior research stressed that excess gestational weight gain is linked to fetal macrosomia [39, 40] and macrosomia has been implicated in an elevated risk of overweight or obesity in childhood as well as during adulthood [41]. This argument was supported by our finding where infants born with very large/larger sizes than average had an elevated risk of being overweight/obesity (S2). Macrosomia is believed to be as a result of hyperglycemia in the fetus as a result insulin, insulin-like growth factors, growth hormone, and other growth factors get activated and in turn, fetal growth and deposition of fat and glycogen are stimulated. All these mechanisms result in childhood overweight and obesity [42, 43].

Breastfeeding is believed to play a vital role in programming non-communicable disease risk later in life [44–47] including prevention of childhood overweight/obesity. Research has found that overweight/obese women are associated with significantly lower rates of breastfeeding initiation, duration, and exclusivity [48, 49]. In addition, factors such as delayed onset of lactogenesis II can decrease the mother's confidence that her milk is sufficient for her child. Also, hormonal imbalances, psychosocial, and mammary hypoplasia could impact breastfeeding and exclusivity [48]. Furthermore, an increase in leptin levels are reported to positively correlate with an increase in maternal BMI and elevated leptin levels in obese women may negatively influence milk availability [50]. Therefore,

these conditions may influence mothers to the start practicing inappropriate feeding practices (early introduction of complementary foods less than six months) that could result in infant's unhealthy weight gain [51]. It is known that total energy intake, protein, and amount of energy metabolized, are higher among formula-fed infants relative to breastfed, hence influencing an increase in body weight during the neonatal period and later in life [52].

Limitations

The cross-sectional nature of the study design did not permit us to establish the cause-and-effect relationships. There might be recall bias, as the perceived size at births were obtained by self-reports. The results are prone to social desirability effect due to the interviewer bias. Other potential confounding factors (e.g. pregnancy history) were not adjusted because this study relied on a secondary data analyses.

CONCLUSIONS

Our findings indicate that high maternal BMI both on the individual- and community-level is associated with overweight/obesity in pre-school-aged children. Therefore, interventions targeting childhood overweight/obesity reduction in Malawi should not only address women and children but also their communities. Specifically, efforts should be concentrated on overweight/obese women of childbearing age throughout pregnancy and beyond through education on proper choices of nutrition, diet, and physical activity patterns.

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CONFLICT OF INTEREST

None declared

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Table 1 Mean, median, mode, standard, kurtosis and skewness of age, height, weight and body mass index among women and preschool children in Malawi

Women	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Mean	28.09	156.04	55.81	23.03
Median	27.00	156.00	53.90	22.18
Mode	23.00	155.00	50.80	20.78
Std Deviation	6.94	5.88	10.79	4.78
Variance	48.22	34.63	116.33	22.83
Skewness	0.53	-0.49	1.59	6.98
Kurtosis	-0.39	4.94	6.00	100.61
Coeff Variation	24.72	3.77	19.33	20.75
Standard Error Mean	0.11	0.09	0.13	0.08
Maximum	49	184.7	162.9	58.25
Minimum	15	100.1	15.7	13.64
Percentiles				
5%	19	147.0	43.4	18.45
10%	20	149.0	45.5	19.12
25% Q1	22	152.3	49.2	20.45
50% Q2	27	156.0	50.4	22.18
75% Q3	33	159.7	60.3	24.57
90%	38	163.3	68.3	27.63
95%	41	165.6	74.5	30.07
Children	**Age (months)**	**Height (cm)**	**Weight (kg)**	**WHZ (z-score)**
Mean	29.41	83.40	11.41	0.09
Median	30.00	84.70	11.50	0.07
Mode	12.00	78.00	10.80	0.03
Std Deviation	16.54	13.00	3.17	1.12
Variance	273.66	169.03	10.06	1.25
Skewness	0.02	-0.35	-0.07	0.04
Kurtosis	-1.13	-0.43	-0.33	1.18
Coeff Variation	56.23	15.59	27.80	1241.95
Standard Error Mean	0.26	0.20	0.05	0.02
Maximum	60	115.5	22.2	4.89
Minimum	0	45.4	2.7	-4.85
Percentiles				
5%	4	59.7	6.1	-1.68
10%	6	65.2	7.2	-1.25
25% Q1	15	74.5	9.2	-0.57
50% Q2	30	84.7	11.5	0.07
75% Q3	43	93.2	13.7	0.78
90%	52	99.4	15.4	1.46
95%	56	102.4	16.4	1.90

N=4023; Std, standard; Q1, first quantile; Q2; second quantile; Q3; third quantile; cm;

centimeter; kg, kilograms; WHZ, Weight/Height standard deviation (new WHO). BMI, body mass index.

Table 2 Descriptive Analysis of Childhood Overweight/Obesity and Individual-level Factors

Characteristic	Overall‡	Overweight/Obesity⁑		
		No	Yes	
	n (%)	*n (%)*	*n (%)*	*p-value*
Mother's nutritional status; BMI (kg/m^2)				0.0011
Underweight (BMI <18.5)	208 (5.17)	203 (97.60)	5 (2.40)	
Normal (BMI 18.5-24.9)	2941 (73.10)	2831 (96.26)	110 (3.74)	
Overweight/obese (BMI ≥25)	874 (21.73)	818 (93.59)	56 (6.41)	
Individual-level factors				
Child characteristics				
Sex of the child				0.0190
Male	1976 (49.12)	1877 (94.99)	99 (5.01)	
Female	2047 (50.88)	1975 (96.48)	72 (3.52)	
Age (months)				<.0001
<12	721 (17.92)	641 (88.90)	80 (11.10)	
12–23	841 (20.90)	806 (95.84)	35 (4.16)	
24–35	887 (22.05)	860 (96.96)	27 (3.04)	
36–47	865 (21.50)	849 (98.15)	16 (1.85)	
≥48	709 (17.62)	696 (98.17)	13 (1.83)	
Size at birth				0.0739
Very small/smaller than average	639 (15.88)	621 (97.18)	18 (2.82)	
Average	2029 (50.43)	1944 (95.81)	85 (4.19)	
Large/larger than average	1355 (33.68)	1287 (94.98)	68 (5.02)	
Preceding birth interval (months)				<.0001
<24	1333 (33.13)	1280 (96.02)	53 (3.98)	
24-47	1420 (35.30)	1380 (97.18)	40 (2.82)	
48+	1270 (31.57)	1192 (93.86)	78 (6.14)	
Maternal/household characteristics				
Mother's age (years)				0.0809
15–24	1465 (36.42)	1393 (95.09)	72 (4.91)	
25–34	1778 (44.00)	1694 (95.71)	76 (4.29)	
35–49	788 (19.58)	765 (97.08)	26 (2.92)	
Mother's education level				0.5098
No education	484 (12.03)	468 (96.69)	16 (3.31)	
Primary	2580 (64.13)	2465 (95.54)	115 (4.46)	
Secondary and above	959 (23.84)	919 (95.83)	40 (4.17)	
Wealth quintile				0.9611
Poorest	837 (20.81)	805 (96.18)	32 (3.82)	
Poor	876 (21.77)	839 (95.78)	37 (4.22)	
Middle	785 (19.51)	749 (95.69)	36 (4.59)	
Richer	765 (19.02)	732 (95.69)	33 (4.31)	
Richest	760 (18.89)	727 (95.66)	33 (4.34)	

Notes: ⁑weight-for-height greater than 2 standard deviations above WHO Child Growth Standards median; ‡N = 4,023; BMI, Body Mass Index; kg/m^2, kilogram per square meter

Table 3 Descriptive Analysis of Childhood Overweight/Obesity and Community-level Factors

Characteristic	Overall	Overweight/Obesity‡		
		No	Yes	
	n (%)	*n (%)*	*n (%)*	*p-value*
Community-level characteristics§				
Percentage of overweight women♀				0.0022
Low ψ	1230 (30.57)	1198 (97.40)	32 (2.60)	
Middle	1375 (34.18)	1310 (95.27)	65 (4.73)	
High	1418 (35.25)	1344 (94.78)	74 (5.22)	
Residence				0.6986
Urban	703 (17.47)	675 (96.02)	28 (3.98)	
Rural	3320 (82.53)	3177 (95.69)	143 (4.31)	
Geographical region				0.9417
Northern	724 (18.00)	692 (95.58)	32 (4.42)	
Central	1415 (35.17)	1354 (95.69)	61 (4.31)	
Southern	1884 (46.83)	1806 (95.86)	78 (4.14)	
Community wealth†				0.9389
Low ψ	1460 (36.29)	1399 (95.82)	61 (4.18)	
Middle	1365 (33.93)	1308 (95.82)	57 (4.18)	
High	1198 (29.78)	1145 (95.58)	53 (4.42)	
Community female education††				0.4964
Low ψ	1399 (34.78)	1346 (96.21)	53 (3.79)	
Middle	1274 (31.67)	1346 (95.29)	60 (4.71)	
High	1350 (33.56)	1292 (95.70)	58 (4.30)	

Notes: ‡*weight-for-height greater than 2 standard deviations above WHO Child Growth Standards median;* §*Clusters N = 850;* ♀*percentage of women in the community categorized as being overweight/obese;* †*percentage of households in the community categorized as richest (upper 40% of quintiles);* ††*percentage of women in the community with primary or higher education;* ψ, categorized with respect to each variable's tertiles.

Table 4 Correlation coefficients⁑ among selected continuous characteristics with child's weight/height z-scores (new WHO‡)

Characteristic		A	B	C	D	E	F	G	H
A	Child's Weight/Height Z-score	1.00000							
B	Mother's BMI	0.10949 <.0001	1.00000						
C	Child's age (months)	-0.09314 <.0001	0.10510 <.0001	1.00000					
D	Preceding birth interval	0.04346 0.0189	0.09121 <.0001	-0.16740 <.0001	1.00000				
E	Mother's age (years)	-0.01521 0.3348	0.11887 <.0001	0.23567 <.0001	0.28005 <.0001	1.00000			
F	Percentage of overweight women♀	0.06725 <.0001	0.30293 <.0001	0.01651 <.0001	0.10046 <.0001	0.04297 0.0064	1.00000		
G	Community wealth†	0.00029 0.9852	0.16828 <.0001	-0.00665 0.6734	0.14949 <.0001	-0.01839 0.2436	0.36698 <.0001	1.00000	
H	Community female education††	0.01528 0.3324	0.10375 <.0001	0.00223 0.8877	0.08358 <.0001	-0.04413 0.0051	0.17985 <.0001	0.42881 <.0001	1.00000

Notes: ⁑*Pearson correlation coefficient;* ‡*WHO, World Health Organization; BMI, Body Mass Index;* ♀*percentage of women in the community categorized as being overweight/obese;* †*percentage of households in the community categorized as richest (upper 40% of quintiles);* ††*percentage of women in the community with primary or higher education.*

Table 5. Measures of Association and Variation between Individual- and Community-level Maternal Body Mass Index‡ and Childhood Overweight/Obesity†

Characteristic	Model I (null)		Model II		Model III		Model IV	
	aOR 95% (CI)	*p*-value	aOR 95% (CI)	*p*-value	aOR 95% (CI)	*p*-value	aOR 95% (CI)	*p*-value
Individual-level factors								
Maternal BMI (kg/m^2)								
Underweight (BMI <18.5)			1.00				1.00	
Normal (BMI 18.5-24.9)			1.58 (0.60–4.12)	0.3487			1.57 (0.60–4.11)	0.3551
Overweight/obese (BMI ≥25)			**3.58 (1.32–9.71)**	**0.0121**			**3.11 (1.13–8.54)**	**0.0277**
Community-level factors								
Percentage of maternal overweight								
Low					1.00		1.00	
Middle					**1.87 (1.17–2.98)**	**0.0086**	**1.68 (1.02–2.78)**	**0.0423**
High					**2.19 (1.36–3.51)**	**0.0012**	**1.69 (1.00–2.90)**	**0.0512**
Measures of variation or clustering								
Random effects								
[τ(SE)]	**0.9011 (0.4072)**	**0.0134**	**1.0586 (0.4637)**	**0.0112**	**0.6878 (0.4171)**	**0.0496**	**0.9174 (0.4624)**	**0.0236**
MOR	2.47		2.67		2.21		2.49	
ICC (%)	21.50		24.34		17.29		21.80	
PCV⁑ (%)	Reference		-17.48		23.67		-1.81	
Model fit statistics								
DIC (-2log likelihood)	1410.86		1273.34		1397.26		1265.55	

Notes: ‡maternal weight in kilograms divided by the square of her height in meters (kg/m^2); †weight-for-height greater than 2 standard deviations above WHO Child Growth Standards median; BMI, Body Mass Index; kg/m2, kilograms per square meters; aOR, adjusted odds ratio; CI, confidence interval; [τ (SE)], community-level variance; SE, standard error; MOR, median odds ration; ICC, intraclass correlation; PCV, proportional change in variance; ⁑the proportional change in variance expresses the change in the community level variance between the null model and the individual level model, and between the individual level model, and the model further including the community level covariate; DIC, deviation information criterion. Model I: unconditional model with random intercepts and had no predictors. Model II: contained a random-intercept fixed-slope and adjusted for individual-level factors; sex of the child, age of child (months), size at birth, preceding birth interval, maternal age, education status, household wealth. Model III: contained a random-intercept fixed-slope and adjusted for community contextual factors; residence, geographical region, percentage of female with primary education and above in the community, percentage of household wealth categorized as richest (upper 60%) in the community. Model IV: contained a random-intercept fixed-slope and controlled for both individual and community-level factors. The Bold texts indicate a statistically significant association at a p-value less than 0.05.