Specific weights of nineteen explanatory variables in low birth weight in the Mayan Zone of the Mexican state of Quintana Roo according to the Multiple Logistic Regression Model. Analytical observational epidemiological study of cases and controls

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ABSTRACT

Low birth weight is an indicator that allows predicting the probability of survival of a child. In fact, there is an exponential relationship between weight deficit, gestational age, and perinatal mortality. In addition, it is important to indicate that a percentage of term children ($37 \leq$ weeks of gestation ≤ 41) who have low birth weight present with various sequelae of variable severity –especially in the neurological sphere– and hence the importance of predicting the presentation of low birth weight. Multiple Logistic Regression is one of the most expressive and versatile statistical instruments available for data analysis in both clinical and epidemiology. Its origin dates to the sixties with the transcendent work of Cornfield, Gordon & Smith on the risk of suffering from coronary heart disease and, in the way we know it today, with the contribution of Walter & Duncan in which addresses the issue of estimating the probability of occurrence of a certain event based on several variables. Its use has been universalized and expanded since the early eighties, due to the computer facilities available since then. Quantitative approach. The study design corresponds to that of an analytical observational epidemiological study of cases and controls with directionality response variable→explanatory variables and with prospective temporality. One thousand eight hundred fifteen newborns were studied [178 (9.81%) cases and 1,637 (90.19%) controls], which corresponds to nine controls per case. All term newborns ($37 \leq$ weeks of gestation ≤ 41) with weights $< 2,500$ g and $\geq 2,500$ g were defined, respectively, as a case and as a control. The values obtained from the β Exponents or Odds Ratios indicate the positive contribution ($OR > 1$) in ascending numerical order of the explanatory variables alcoholism (0.0018); low socioeconomic level (0.5694); initiation of prenatal care from or after the 20th week of gestation (0.6116); birth interval ≤ 24 months (0.7942); age at menarche ≤ 12 years (1.0792); “unmarried” marital status (1.0961); female gender of the product (1.1271); maternal weight $<$

50 kg (1.4700); history of abortion(s) (1.5407); number of deliveries = 1 (1.5524); number of prenatal visits ≤ 5 (1.5966); type of delivery or abdominal birth route (1.6169); smoking (2.2019); number of deliveries ≥ 5 (2.2714); maternal age ≤ 19 years (2.4827); maternal age ≥ 36 years (2.8070); pathological obstetric history (4.0735); pathological personal history (4.6475); and maternal height < 150 cm (5.5092).

1 INTRODUCTION

Low birth weight has been a mystery to science throughout the ages. Multiple have been the investigations carried out about the causes that produce it and the consequences that it causes (Lemus–Lago *et al.*, 2017).

Birth weight is one of the variables recognized among the most important due to its association with the increased risk of mortality in any period, especially in the perinatal period. It is, without doubt, the most important determinant of a newborn's chances of experiencing satisfactory growth and development. For this reason, currently, the rate of low–birth–weight newborns is considered as a general health indicator (Hernández–Cisneros *et al.*, 2016), since it is multifactorial due to both maternal problems and fetal and environmental problems (Cuba de la Cruz *et al.*, 2016). These children typically have multiple later problems in the perinatal period, in childhood, and even into adulthood. Among these problems are poor adaptation to the environment and different physical and mental impediments that become evident when school age is reached (Resnick *et al.*, 2017).

Programs aimed at reducing the rate of low–birth–weight show that children born with a weight $< 2,500$ g have a 14 times higher risk of mortality during the first year of life compared to children born with a weight normal (Peraza–Roque *et al.*, 2015). When the cause of low weight has been intrauterine growth retardation, it can become irreversible after birth and is usually accompanied by lower–than–normal mental functions and neurological and intellectual sequelae. Low birth weight is a global concern and is much more prevalent in underdeveloped countries. Low birth weight can be due to the following two fundamental causes: 1. Having had a birth before the term of gestation (preterm delivery < 37 weeks of gestation); or 2. The fetus is underweighting in relation to its gestational age (intrauterine malnutrition and delayed intrauterine growth). Preterm delivery has been associated with the very young age of the mother, with the rapid succession of pregnancies, with the permanent dilation of the cervix and with various diseases or complications of pregnancy. In turn, delayed intrauterine growth has been related to maternal malnutrition and to environmental and social factors. It can be considered, at times, as a generational effect (Duanis–Neyra & Neyra–Álvarez, 2018).

A quite common problem in research is to determine the effects of each of the explanatory variables on some response. In the past, it was recommended that each factor be studied at the same time, dedicating a test of statistical significance to it (bivariate analysis). Later, Fisher indicated that significant

advantages are obtained if several factors are combined in the same analysis (multivariate analysis) (Fisher, 1951).

The Multiple Logistic Regression Model is highly effective because each observation provides information about all the factors included in the analysis (Fleiss, 1973).

Multiple Logistic Regression is one of the most expressive and versatile statistical instruments available for data analysis in clinical and epidemiology. Its origin dates to the sixties with the transcendent work of Cornfield, Gordon & Smith on the risk of suffering from coronary heart disease (Cornfield *et al.*, 1961) and, in the way we know it today, with the contribution of Walter & Duncan in which the issue of estimating the probability of occurrence of a certain event based on several variables is addressed (Walter & Duncan, 2013).

Wald (1943) studied an asymptotic test for maximum plausible estimates and stated that the parameters estimated in the Logistic Models have a normal distribution for large samples. This test is used to evaluate the statistical significance (α) of each explanatory variable (Lemonte & Vanegas, 2005).

In summary, the general objective of Multiple Logistic Regression is to predict the probability of an event of interest in an investigation, as well as to identify useful explanatory variables for such prediction.

The Hosmer–Lemeshow goodness of fit test assesses the goodness of fit of the Model, that is, the degree to which the predicted probability coincides with the observed probability by constructing a contingency table to which a χ^2 test is applied. To do this, he calculates the deciles of the estimated probabilities and divides the observed data into ten categories (Fagerland & Hosmer, 2012).

Using the Multiple Logistic Regression Model, this work was aimed at evaluating the specific weights of nineteen explanatory variables in low birth weight in children born in four health service institutions (Integral Hospital “Lazaro Cardenas”; General Hospital “Felipe Carrillo Puerto”; Integral Hospital “Jose Maria Morelos”; and Integral Hospital “Tulum”) of the Mayan Zone of the Mexican state of Quintana Roo, in order to detect those explanatory variables that can be modified via health interventions public by the corresponding health authorities.

2 GENERAL OBJECTIVE

To multivariately evaluate the specific weights of nineteen explanatory variables in the low birth weight of children born in four health services institutions in the Mayan Zone of the Mexican state of Quintana Roo.

3 SPECIFIC OBJECTIVES

Evaluate the contribution (positive, negative or null) using the β Exponents or Odds Ratio of nineteen explanatory variables in low birth weight through different types of statistical significance tests; and

Predict the value of the probability of low birth weight (response variable “Y”) by applying the Multiple Regression Logistic Model given determined values of explanatory variables ($X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}$).

4 HYPOTHESIS FORMULATION

4.1 NULL HYPOTHESIS (H_0)

The values of the β Exponents or Odds Ratios are ≤ 1 which indicates a null contribution ($OR = 1$) or a negative contribution ($OR < 1$), respectively. Additionally, there is no statistically significant evidence at the significance level (α) of 5% to conclude that the response variable (low birth weight) and the explanatory variables are associated.

4.2 ALTERNATIVE HYPOTHESIS, WORKING HYPOTHESIS OR RESEARCH HYPOTHESIS (H_1)

The values of the β Exponents or Odds Ratios are > 1 which indicates a positive contribution ($OR > 1$). Additionally, there is statistically significant evidence at the significance level (α) of 5% to suppose that the response variable (low birth weight) and the explanatory variables are associated.

5 MATERIAL AND METHODS

5.1 EPISTEMOLOGICAL APPROACH

Quantitative Approach, Probabilistic Approach Or Positivist Approach (Hernández-Sampieri Et Al., 2006).

5.2 STUDY DESIGN

Analytical observational epidemiological study of cases and controls with directionality (response variable $\rightarrow$ explanatory variables) and with prospective temporality (Hernández-Ávila, 2007).

5.3 STUDY UNIVERSE

Births (cases and controls that met the inclusion criteria) occurred in four health service institutions in the Mayan Zone of the Mexican state of Quintana Roo during the period from February 1, 2019 to January 31, 2020 were registered.

The Mexican state of Quintana Roo is divided into ten municipalities, seven of which were created in 1974 together with the elevation to the rank of “State of the Federation” of the former “Federal Territory of Quintana Roo”. The eighth municipality, Solidaridad, was created in 1993; the ninth municipality, Tulum, in 2008; and the tenth municipality, Bacalar, in 2011. The origin of the municipalities of the Mexican state of Quintana Roo comes from the former initial division of the territory into three delegations: Cozumel, Santa Cruz de Bravo (today Felipe Carrillo Puerto) and Payo Obispo (today Chetumal). Even when the Constitution of 1917 established that the base of the political organization of the states is the Free Municipality, the Federal Territories continued divided into delegations until their respective elevation to the rank of States. On February 2, 2011, the creation of the tenth municipality of Quintana Roo, Bacalar, with segregated territory from Othon Pompeyo Blanco, was announced. On February 21, 2008, the Congress of Quintana Roo approved the preliminary project for the creation of the municipality of Tulum, which obtained its territory from the current municipality of Solidaridad and includes the Tulum National Park and parts of the Sian Kan Biosphere Reserve; this was formally ratified when on March 13 the Congress of Quintana Roo unanimously approved the creation of the municipality of Tulum.

Figure 1. Map of the Mexican state of Quintana Roo

5.4 OPERATIONAL DEFINITIONS OF THE VARIABLES

Case.– All term newborn ($37 \leq$ weeks of gestation ≤ 41) weighing $< 2,500$ g;

Control.– All term newborn ($37 \leq$ weeks of gestation ≤ 41) weighing $\geq 2,500$ g;

Maternal age.– Period of time elapsed from the date of the mother's birth to the date of delivery. It was registered in completed years. Maternal ages ≤ 19 and ≥ 36 years were considered explanatory variables. Continuous quantitative variable;

Maternal weight.– It was recorded in kg. An explanatory variable was considered a maternal weight < 50 kg. Continuous quantitative variable;

Maternal stature.– Height measured from feet to head. It was recorded in cm. An explanatory variable was considered a maternal height < 150 cm. Continuous quantitative variable;

Pathological personal history.– Jurisdictions registered as “yes” or as “no”. An explanatory variable was considered to have a pathological personal history. Nominal qualitative variable;

Age at menarche.– Age at which the first menstrual cycle occurred. It was registered in completed years. An explanatory variable was considered an age at menarche ≤ 12 years. Continuous quantitative variable;

Parity.– Number of deliveries of the mother, including the current one. Explanatory variables were considered one delivery (primiparity) and ≥ 5 deliveries (multiparity). Discrete or discontinuous quantitative variable;

History of abortion(s).– Termination of pregnancy due to variable natural or deliberately provoked responses. It was recorded as “yes” or as “no”. An explanatory variable was considered to have a history of abortion(s). Nominal qualitative variable;

Pathological obstetric antecedents.– They were registered as “yes” or as “no”. An explanatory variable was considered to have a pathological obstetric history. Nominal qualitative variable;

Birth interval.– Period of time elapsed from the date of the birth of the penultimate child to the date of the current birth. It was recorded in full months. An explanatory variable was considered an intergenetic interval ≤ 24 months. Continuous quantitative variable;

Socioeconomic level.– It was registered as “low” or as “medium”. An explanatory variable was considered a low socioeconomic level. Ordinal qualitative variable. It is worth mentioning that the state health services that provide medical–assistance services through their application units apply the tabulator that contains the classification of the different services with six levels of recovery fees for each service. These levels are applied based on the score that results from the socioeconomic record established at the national level;

Marital status.— She was registered as single, married, divorced, separated, common-law union and widow. Later the marital statuses single, divorced, separated, common law and widow were recoded as “not-married”. The “not-married” status was considered an explanatory variable. Nominal qualitative variable;

Smoking.— It was registered as “yes” or as “no”. Smoking ≥ 10 cigarettes per day was considered an explanatory variable. Nominal qualitative variable;

Alcoholism.— It was registered as “yes” or as “no”. An explanatory variable was considered to drink a beer daily, or to drink intoxicating beverages at least three times a week. Nominal qualitative variable;

Gestational week at the beginning of prenatal care.— It was registered as “from or after the 20th week of gestation” or as “before the 20th week of gestation”. An explanatory variable was considered “from or after the 20th week of gestation”. Discrete or discontinuous quantitative variable;

Number of prenatal visits.— It was recorded as “ ≤ 5 prenatal visits” or as “ ≥ 6 prenatal visits”. An explanatory variable was considered to have “ ≤ 5 prenatal visits”. Qualitative ordinal variable;

Type of delivery or route of birth.— Childbirth is the culmination of pregnancy; the exit of a product from the womb. It was registered as “vaginal” or as “abdominal”. The type of delivery or abdominal birth route was considered an explanatory variable. Nominal qualitative variable; and

Product gender.— It was registered as “male” or as “female”. The “female” gender of the product was considered an explanatory variable. Nominal qualitative variable.

5.5 INCLUSION CRITERIA

Products of “ $37 \leq$ weeks of gestation ≤ 41 ” born in the Integral Hospital “Lazaro Cardenas”; in the General Hospital “Felipe Carrillo Puerto”; in the Integral Hospital “Jose Maria Morelos”; and in the Integral Hospital “Tulum” during the study period were included.

5.6 EXCLUSION CRITERIA

Products of “ $37 \leq$ weeks of gestation ≤ 41 ” born in the four health service institutions during the study period were excluded.

5.7 ELIMINATION CRITERIA

Multiple births, newborns with congenital malformations such as Down syndrome and newborns who do not have the complete information required during the study period.

5.8 TECHNIQUES AND PROCEDURES

The necessary information was collected in the Clinical Archives Departments of the Integral Hospital “Lazaro Cardenas”; of the General Hospital “Felipe Carrillo Puerto”; of the Integral Hospital “Jose Maria Morelos”; and the Integral Hospital “Tulum” during the period from February 1, 2019 to January 31, 2020.

The data were collected from the corresponding databases, from the clinical records of the newborns and from the clinical records of the mothers.

5.9 DATA PROCESSING

The data were reviewed (information quality control); classified (on qualitative and quantitative scales); computerized (the IBM SPSS Statistics software for Windows, Version 22 was used); presented (Tables, Graphs and Figures); summarized (corresponding summary measures were used for data classified on qualitative and quantitative scales); analyzed; and interpreted. For the elaboration of the graphs, the Excel Microsoft 365 software for Windows and Harvard Graphics ChartXL for Windows, Version 3.02 were used.

The use of the Bonferroni adjustment method was planned to adjust the level of significance in relation to the number of statistical tests performed simultaneously on a set of data. The level of significance for each test was calculated by dividing the global type I error or global type α error by the number of tests to be performed (<http://www.e-biometria.com/glosario/glosario.htm>) in order to correct the inconvenience that variables with many categories are more likely to be selected as explanatory; although it has no effect with dichotomous variables (www.ugr.es/~franml/files/im2/guia07CHAID.pdf), it allows for “n” contrasts to maintain the overall probability $\leq 5\%$ (<http://www.seh-lilha.org/subgrupos.htm>). Considering the above, nineteen contrasts were carried out, consequently, a value of $\alpha = 0.0026$ for a $p \leq 0.0500$; therefore, the values $p > 0.0026$ and $p \leq 0.0026$ were taken to accept or reject, respectively, the null hypothesis; the above, as long as the explanatory variable has more than two categories.

To estimate the association between the response variable and the explanatory variables, a Multiple Logistic Regression analysis was performed.

The probability of appearance of low birth weight was calculated for all observation units using the Hosmer–Lemeshow goodness of fit test (Hosmer & Lemeshow, 1989) based on the distribution of cases and controls predicted by the equation and the values actually observed. Both expected and observed distributions were contrasted using Wald’s χ^2 statistic (χ^2_w) (<http://www.seh-lilha.org/rlogis1.htm>).

6 RESULTS

Table 1 shows the response variable and the explanatory variables according to their recoding for the Multiple Logistic Regression Analysis.

Table 1. Response variable “Y” and explanatory variables “X_i” according to recoding for Multiple Logistic Regression Analysis. 1/II/2019–31/I/2020.

Response variable (Y) and Explanatory variables (X _i)	Recoding
Full-term newborn weight (37 ≤ weeks of gestation ≤ 41)	0= ≥ 2,500 g 1= < 2,500 g
Maternal age	0= 20–35 years 1= ≤ 19 years 2= ≥ 36 years
Maternal weight	0= ≥ 50 kg 1= < 50 kg
Maternal height	0= ≥ 150 cm 1= < 150 cm
Pathological personal history	0= No 1= Yes
Age at menarche	0= ≥ 13 years 1= ≤ 12 years
Number of deliveries	0= 2–4 1= 1 2= ≥ 5
History of abortion(s)	0= No 1= Yes
Pathological obstetric history	0= No 1= Yes
Birth interval	0= > 24 months 1= ≤ 24 months
Socioeconomic level	0= Medio 1= Bajo
Civil status	0= Married 1= Not married
Smoking	0= No 1= yes
Alcoholism	0= No 1= yes
Gestational week at the beginning of prenatal care	0= Before the 20th week of gestation 1= From or after the 20th week of gestation
Number of prenatal visits	0= ≥ 6 1= ≤ 5
Type of delivery or route of birth	0= Vaginal 1= Abdominal
Product gender	0= Male 1= Female

Source. Own elaboration

Regarding the performance of the Multiple Logistic Regression Analysis in the four health services institutions of the Mayan Zone of the Mexican state of Quintana Roo, the values obtained indicate the positive contribution ($OR > 1$) in ascending numerical order of the explanatory variables alcoholism; low socioeconomic status; initiation of prenatal care from or after the 20th week of gestation; birth interval ≤ 24 months; age at menarche ≤ 12 years; “not-married” marital status; female gender of the product; maternal weight < 50 kg; history of abortion(s); number of deliveries = 1; number of prenatal visits ≤ 5 ; type of delivery or abdominal birth route; smoking; number of deliveries ≤ 5 ; maternal age ≤ 19 years; maternal age ≥ 36 years; pathological obstetric history; pathological personal history; and maternal height < 150 cm. The determinants of low birth weight found in the four Mayan municipalities and that can be modified via public health interventions, health education programs and change to healthy lifestyles are: 1) Alcoholism; 2) Beginning of prenatal care from or after the 20th week of gestation; 3) Birth interval ≤ 24 months; 4) “Unmarried” marital status; 5) Maternal weight < 50 kg; 6) Number of prenatal visits ≤ 5 ; 7) Smoking; 8) Number of deliveries ≥ 5 ; 9) Maternal age ≤ 19 years; 10) Maternal age ≥ 36 years; and 11) Maternal height < 150 cm.

The explanatory variables according to the results of the Multiple Logistic Regression Analysis are presented in Table 2.

Table 2. Explanatory variables according to the results of the Multiple Logistic Regression Analysis. Lazaro Cardenas, Felipe Carrillo Puerto, Jose Maria Morelos and Tulum, Quintana Roo, Mexico. 1/II/2019–31/I/2020.

Explanatory variables	Estimated logistic coefficients (β)	Estimated standard errors	Wald chi-square statistics (χ^2_w)	Degrees of freedom (df)	Probabilities (p)	β Exponents or Odds Ratios	Estimation intervals at the 95% confidence level
Biological characteristics of the mother							
Maternal age ≤ 19 years	0.9093	0.6000	2.2969	1	0.1296	2.4827	0.7659→8.0473
Maternal age ≥ 36 years	1.0321	0.6176	2.7928	1	0.0947	2.8070	0.8366→9.4175
Maternal weight < 50 kg	0.3852	0.2138	3.2465	1	0.0716	1.4700	0.9668→2.2351
Maternal height < 150 cm	1.7064	0.1972	74.8540	1	0.0000	5.5092	3.7429→8.1091
Pathological personal history	1.5363	0.3023	25.8328	1	0.0000	4.6475	2.5700→8.4046
Mother's obstetric history							
Age at menarche ≤ 12 years	0.0763	0.1970	0.1499	1	0.6986	1.0792	0.7336→1.5878
Number of deliveries = 1	0.4398	0.6248	0.4954	1	0.4815	1.5524	0.4562→5.2827
Number of deliveries ≥ 5	0.8204	0.6342	1.6736	1	0.1958	2.2714	0.6554→7.8719
History of abortion(s)	0.4323	0.3089	1.9588	1	0.1616	1.5407	0.8411→2.8225

Pathological obstetric history	1.4045	0.4009	12.2760	1	0.0005	4.0735	1.8567→8.9367
Birth interval ≤ 24 months	-0.2304	0.1920	1.4409	1	0.2300	0.7942	0.5451→1.1570
Mother's social characteristics							
Low socioeconomic status	-0.5632	0.4151	1.8410	1	0.1748	0.5694	0.2524→1.2845
Unmarried marital status	0.0917	0.2366	0.1503	1	0.6983	1.0961	0.6894→1.7427
Smoking	0.7893	1.2353	0.4082	1	0.5229	2.2019	0.1956→24.7928
Alcoholism	-6.3457	9.2474	0.4709	1	0.4926	0.0018	0.0000→130475.06
Characteristics of prenatal care							
Beginning of prenatal care from week 20 of gestation	-0.4917	0.2363	4.3308	1	0.0374	0.6116	0.3849→0.9718
Number of prenatal visits ≤ 5	0.4679	0.2190	4.5630	1	0.0327	1.5966	0.0394→2.4526
Characteristic of delivery							
Type of delivery or abdominal birth route	0.4805	0.1879	6.5423	1	0.0105	1.6169	1.1189→2.3367
Product Feature							
Product female gender	0.1197	0.1761	0.4619	1	0.4967	1.1271	0.7982→1.5916
Constant or intercept	-4.8318	0.9442	26.1900	1	0.0000		

Source. Own elaboration from the results obtained with the IBM SPSS Statistics software for Windows, Version 22

Interpretation of the values of the statistic χ^2 of Wald (χ^2_w):

1. When χ^2_w is ≥ 3.8416 there is significance; and
2. When χ^2_w is < 3.8416 there is no significance.

Interpretation of the probability values (p):

1. When p is ≤ 0.0500 there is significance; and
2. When p is > 0.0500 there is no significance.

Interpretation of the values of the β Exponents or Odds Ratios (OR):

1. When $OR > 1$ the variable is a risk factor;
2. When $OR < 1$ the variable is a protection factor; and
3. When $OR = 1$, the variable is not a risk factor, nor is it a protection factor.

Interpretation of the values of the estimation intervals at the 95% confidence level (95% CI):

1. When the estimation interval at the 95% confidence level contains the unit (1) there is no significance; and
2. When the estimation interval at the 95% confidence level does not contain unity (1), there is significance.

Table 3 shows the explanatory variables according to the values of the β Exponents or Odds Ratios in ascending numerical order by health service institutions in the Mayan Zone of the Mexican state of Quintana Roo.

Table 3. Explanatory variables according to the values of the β Exponents or Odds Ratios in ascending numerical order by health service institutions in the Mayan Zone of the Mexican State of Quintana Roo. 1/II/2019–31/I/2020.

Health Service Institutions Mayan Zone of the Mexican State of Quintana Roo	
Explanatory variables	β Exponents or Odds Ratios
1. Alcoholism	0.0018
2. Low socioeconomic status	0.5694
3. Beginning of prenatal care from week 20 of gestation	0.6116
4. Birth interval ≤ 24 months	0.7942
5. Age at menarche ≤ 12 years	1.0792
6. Unmarried marital status	1.0961
7. Female gender of the product	1.1271
8. Maternal weight < 50 kg	1.4700
9. History of abortion(s)	1.5407
10. Number of deliveries = 1	1.5524
11. Number of prenatal visits ≤ 5	1.5966
12. Type of delivery or abdominal birth route	1.6169
13. Smoking	2.2019
14. Number of deliveries ≥ 5	2.2714
15. Maternal age ≤ 19 years	2.4827
16. Maternal age ≥ 36 years	2.8070
17. Pathological obstetric history	4.0735
18. Personal pathological history	4.6475
19. Maternal height < 150 cm	5.5092

Source. Own elaboration

In Graph 1 the explanatory variables are presented according to values in ascending numerical order of the β Exponents or Odds Ratios of the Multiple Logistic Regression Analysis.

Graph 1. Explanatory variables according to the values of the β Exponents or Odds Ratios in ascending numerical order by health service institutions in the Mayan Zone of the Mexican State of Quintana Roo. 1/II/2019–31/I/2020.

Source. Table 3

6.1 LOGISTIC MODEL AND EXAMPLE

If the response variable is denoted by “Y”, then it can be assumed that “Y” takes the values zero (0) or one (1). Zero (0) denotes the non-occurrence and one (1) denotes the occurrence of the event (low birth weight). If $X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}$ and X_{19} are explanatory variables related to the occurrence of the response variable “Y”, then the following Logistic Model specifies that the conditional probability of occurrence of the event “Y” given the values $X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}$ is:

$$p(Y=1 | X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}) = \frac{1}{1 + \text{Exponent} - (-\phi)}$$

Where:

$p(Y=1)$ = Probability of being born with low weight; and

$$(\phi) = [\beta_0 + (\beta_1 * X_1) + (\beta_2 * X_2) + (\beta_3 * X_3) + (\beta_4 * X_4) + (\beta_5 * X_5) + (\beta_6 * X_6) + (\beta_7 * X_7) + (\beta_8 * X_8) + (\beta_9 * X_9) + (\beta_{10} * X_{10}) + (\beta_{11} * X_{11}) + (\beta_{12} * X_{12}) + (\beta_{13} * X_{13}) + (\beta_{14} * X_{14}) + (\beta_{15} * X_{15}) + (\beta_{16} * X_{16}) + (\beta_{17} * X_{17}) + (\beta_{18} * X_{18}) + (\beta_{19} * X_{19})]$$

Table 4 shows the values of the estimated logistic coefficients (β) according to explanatory variables (X_i).

Table 4. Estimated logistic coefficients (β) according to explanatory variables (X_i). 1/II/2019–31/I/2020.

Explanatory variables (X_i)	Estimated logistic coefficients (β)
Constant or intercept	$\beta_0 = -4.8318$
$X_1 = \text{Maternal age} \leq 19 \text{ years}$	$\beta_1 = 0.9093$
$X_2 = \text{Maternal age} \geq 36 \text{ years}$	$\beta_2 = 1.0321$
$X_3 = \text{Maternal weight} < 50 \text{ kg}$	$\beta_3 = 0.3852$
$X_4 = \text{Maternal height} < 150 \text{ cm}$	$\beta_4 = 1.7064$
$X_5 = \text{Pathological personal history}$	$\beta_5 = 1.5363$
$X_6 = \text{Age at menarche} \leq 12 \text{ years}$	$\beta_6 = 0.0763$
$X_7 = \text{Number of deliveries} = 1$	$\beta_7 = 0.4398$
$X_8 = \text{Number of deliveries} \geq 5$	$\beta_8 = 0.8204$
$X_9 = \text{History of abortion(s)}$	$\beta_9 = 0.4323$
$X_{10} = \text{Pathological obstetric history}$	$\beta_{10} = 1.4045$
$X_{11} = \text{Birth interval} \leq 24 \text{ months}$	$\beta_{11} = -0.2304$
$X_{12} = \text{Low socioeconomic level}$	$\beta_{12} = -0.5632$
$X_{13} = \text{Marital status "not-married"}$	$\beta_{13} = 0.0917$
$X_{14} = \text{Smoking}$	$\beta_{14} = 0.7893$
$X_{15} = \text{Alcoholism}$	$\beta_{15} = -6.3457$
$X_{16} = \text{Beginning of prenatal care on or after the 20th week of gestation}$	$\beta_{16} = -0.4917$
$X_{17} = \text{Number of prenatal visits} \leq 5$	$\beta_{17} = 0.4679$
$X_{18} = \text{Type of delivery or abdominal birth route}$	$\beta_{18} = 0.4805$
$X_{19} = \text{Female gender of the product}$	$\beta_{19} = 0.1197$

Source. Own elaboration

Therefore, substituting in the Equation we obtain:

$$p(Y=1 | X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17} + X_{18} + X_{19}) = \frac{1}{1 + \text{Exponent} [\beta_0 + (\beta_1 * X_1) + (\beta_2 * X_2) + (\beta_3 * X_3) + (\beta_4 * X_4) + (\beta_5 * X_5) + (\beta_6 * X_6) + (\beta_7 * X_7) + (\beta_8 * X_8) + (\beta_9 * X_9) + (\beta_{10} * X_{10}) + (\beta_{11} * X_{11}) + (\beta_{12} * X_{12}) + (\beta_{13} * X_{13}) + (\beta_{14} * X_{14}) + (\beta_{15} * X_{15}) + (\beta_{16} * X_{16}) + (\beta_{17} * X_{17}) + (\beta_{18} * X_{18}) + (\beta_{19} * X_{19})]}$$

Note.— Although in the present study nineteen explanatory variables have been studied, the proposed Logistic Model contains only seventeen values of the estimated logistic coefficients “ β ” and seventeen values of the explanatory variables (X_i) due to the fact that the explanatory variables maternal age and number of deliveries have two exposure categories which are mutually exclusive, that is, a mother is either ≤ 19 years old or ≥ 36 years old; the same happens with the number of deliveries, since a mother either has 1 delivery or has ≥ 5 deliveries.

The above explains why the explanatory variables maternal age ≤ 19 years (X_1) are not included in the Equation; and number of deliveries = 1 (X_7).

Example:

With the following characteristics, what is the probability that a mother will have a product with low birth weight?

Age ≥ 36 years; weight < 50 kg; height < 150 cm; pathological personal history; age at menarche ≤ 12 years; number of deliveries ≥ 5 ; history of abortion(s); pathological obstetric history; birth interval ≤ 24 months; low socioeconomic level; marital status “not-married”; smoking; alcoholism; beginning of prenatal care on or after the 20th week of gestation; number of prenatal visits ≤ 5 ; type of delivery or abdominal birth route; and female gender of the product.

$$p(Y=1 \mid X_2, X_3, X_4, X_5, X_6, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}) = 1 / 1 + \text{Exponent } -(-\phi)$$

Where:

- $-\phi = -[(-4.8318) + (1.0321*1) + (0.3852*1) + (1.7064*1) + (1.5363*1) + (0.0763*1) + (0.8204*1) + (0.4323*1) + (1.4045*1) + (-0.2304*1) + (-0.5632*1) + (0.0917*1) + (0.7893*1) + (-6.3457*1) + (-0.4917*1) + (0.4679*1) + (0.4805*1) + (0.1197*1)]$;
- $-\phi = -[(-4.8318) + (1.0321) + (0.3852) + (1.7064) + (1.5363) + (0.0763) + (0.8204) + (0.4323) + (1.4045) + (-0.2304) + (-0.5632) + (0.0917) + (0.7893) + (-6.3457) + (-0.4917) + (0.4679) + (0.4805) + (0.1197)]$;
- $-\phi = -(-3.1202)$
- $\phi = 3.1202 = 0.0441$

Then, substituting in Equation we have:

- $p(Y=1 \mid X_2, X_3, X_4, X_5, X_6, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}) = 1 / 1 + 0.0441$
- $p(Y=1 \mid X_2, X_3, X_4, X_5, X_6, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}) = 1 / 1.0441$
- $p(Y=1 \mid X_2, X_3, X_4, X_5, X_6, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}) = 0.9578$

Therefore, with these characteristics, the probability that a mother has a product with low birth weight is 0.9578, which, expressed as a percentage, is equal to 95.78%.

7 DISCUSSION

In compliance with the general objective, the specific weights of nineteen explanatory variables of the low birth weight of children born in four health services institutions in the Mayan Zone of the Mexican state of Quintana Roo, were multivariately evaluated.

The values obtained from the β Exponents or Odds Ratios indicated the positive contribution ($OR > 1$) in ascending numerical order of the explanatory variables alcoholism (0.0018); low socioeconomic level (0.5694); initiation of prenatal care from or after the 20th week of gestation (0.6116); birth interval ≤ 24 months (0.7942); age at menarche ≤ 12 years (1.0792); “unmarried” marital status (1.0961); female gender of the product (1.1271); maternal weight < 50 kg (1.4700); history of abortion(s) (1.5407); number of deliveries = 1 (1.5524); number of prenatal visits ≤ 5 (1.5966); type of delivery or abdominal route of birth (1.6169); smoking (2.2019); number of deliveries ≥ 5 (2.2714); maternal age ≤ 19 years (2.4827); maternal age ≥ 36 years (2.8070); pathological obstetric history (4.0735); pathological personal history (4.6475); and maternal height < 150 cm (5.5092).

The values of the statistic Chi-Square of Wald (χ^2_w) and the values of the corresponding probabilities (p) reported fifteen β Exponents or $OR > 1$ of which only six were statistically significant: $\chi^2_w(\alpha = 0.0500; gl = 1) \geq 3.8416$; $p \leq 0.0500$.

In observance of the first specific objective, the positive, negative or null contribution of the nineteen explanatory variables was evaluated using the values of their corresponding β Exponents or Odds Ratios. Fifteen explanatory variables with positive contribution ($OR > 1$) and four explanatory variables with negative contribution ($OR < 1$) were found.

Finally, in observance of the second specific objective, the value of the probability of low birth weight (response variable “Y”) was predicted by applying the Multiple Regression Logistic Model given determined values of explanatory variables $X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}$. The applied Equation corresponds to the following Logistic Model:

$$1. \quad p(Y = 1 \mid X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}) = \frac{1}{1 + \text{Exponent}^{-(\phi)}}$$

Regarding the formulation of the hypotheses, it can be concluded, in general terms, the rejection of the null hypothesis (H_0) and the acceptance of the alternative hypothesis (H_1).

Our results are consistent with those obtained by other authors (Bergner & Susser, 1970; Jurado-García, 1970; Habicht *et al.*, 1973; Sever *et al.*, 1975; Sinclair & Saigal, 1975; Fedrick & Adelstein, 1978; Galbraith *et al.*, 1979; Beal, 1981; Pitkin, 1981; van den Berg, 1981; Arias & Tomich, 1982; Benício *et al.*, 1985; Casanueva, 1988; Elorza, 1988; Victora *et al.*, 1989; Buyse, 1990; Ganzer, 1991; Cabrales-

Escobar *et al.*, 2002; Martin *et al.*, 2003; Soriano–Llora *et al.*, 2003; Vangen *et al.*, 2003; Fernández–González *et al.*, 2004; Jewell *et al.*, 2004; Lumley *et al.*, 2004; Mota–Sanhua *et al.*, 2004; Beal, 2013; Langer y Arroyo, 2013; Doctor *et al.*, 2015; Franco–Monsreal *et al.*, 2015; Gama *et al.*, 2015; Silva *et al.*, 2015; Abdulrazzaq *et al.*, 2016; Aguilar, 2016; Bakketeig *et al.*, 2016; Becerra *et al.*, 2016; Bratton *et al.*, 2016; Brown *et al.*, 2016; Chaturachinda *et al.*, 2016; Chen *et al.*, 2016; Chomitz *et al.*, 2016; Díaz–Alonso *et al.*, 2016; Díaz–Tabares *et al.*, 2016; Faúndes *et al.*, 2016; Hernández–Cisneros *et al.*, 2016; Liang *et al.*, 2016; Lieberman *et al.*, 2016; López, 2016; Millar *et al.*, 2016; Pagola–Prado, 2016; Rama–Sastryd, 2016; Risiko, 2016; Rosell–Juarte *et al.*, 2016; Sung *et al.*, 2016; Abel, 2017; Bakewell *et al.*, 2017; Barros *et al.*, 2017; Bergsjo & Villar, 2017; Brett *et al.*, 2017; Fuentes–Afflick & Lurie, 2017; Goldenberg *et al.*, 2017; Lemus–Lago *et al.*, 2017; Nault, 2017; Romera y Fernández, 2017; Santos–Pereira–Solla *et al.*, 2017; Bortman, 2018; Cnattingius *et al.*, 2018; Duanis–Neyra & Neyra–Álvarez 2018; Halpern *et al.*, 2018; Moore *et al.*, 2018; Ruiz–Linares *et al.*, 2018; Silva *et al.*, 2018; Aguilar–Valdés *et al.*, 2019; Campbell *et al.*, 2019; Deodhar & Jarad, 2019; Lightwood *et al.*, 2019; Miller & Mvula, 2019; Stratton *et al.*, 2019; Ventura *et al.*, 2019; Xiong *et al.*, 2019; Bouckaert, 2020; Hall, 2020; Najmi, 2020; Windham *et al.*, 2020) as explanatory variables associated with the presentation of low birth weight.

The determinants of low birth weight that can be modified via public health interventions, health education programs and change to healthy lifestyles are: 1) Alcoholism; 2) The beginning of prenatal care from or after the 20th week of gestation; 3) The birth interval ≤ 24 months; 4) The “not–married” marital status; 5) Maternal weight < 50 kg; 6) The number of prenatal visits ≤ 5 ; 7) Smoking; 8) The number of deliveries ≥ 5 ; 9) Maternal age ≤ 19 years; 10) Maternal age ≥ 36 years; and 11) maternal height < 150 cm.

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