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Statistical-mathematical analysis of childhood caries in children between the ages of one and thirteen years as a function of diet and oral hygiene

O. Marín-Machuca[1*], Y. E. Humala-Caycho[2], L. A. Perez-Ton[3], J. E. Candela-Díaz[4], U. Marín-Sánchez[5], M. Rojas-Rueda[6], L.G. Jáuregui-del-Águila[7], H.G. Fuertes-Vicente[8]

[1]Professional School of Food Engineering, Faculty of Oceanography, Fisheries, Food Sciences and Aquaculture, Environmental Sustainability Research Group (GISA), Graduate School. National University Federico Villarreal, Lima, Peru; omarín@unfv.edu.pe (O.M.M.)
[2]Professional School of Food Engineering, Faculty of Oceanography, Fisheries, Food Sciences and Aquaculture. National University Federico Villarreal, Lima, Peru; yhumala@unfv.edu.pe (Y.E.H.C.)
[3]Professional School of Food Engineering, Faculty of Fishery and Food Engineering, National University of the Callao, Callao, Perú; laperezt@unac.edu.pe (L.A.P.T.)
[4]Food Technology Laboratory. Professional School of Food Engineering, Faculty of Oceanography, Fisheries, Food Sciences and Aquaculture, National University Federico Villarreal, Lima, Peru; jcandela@unfv.edu.pe (J.E.C.D.)
[5]General Directorate of Environmental Affairs of Industry (DGAAMI). Ministry of Production (PRODUCE); umarins@produce.gob.pe (U.M.S.)
[6]School of Human Medicine, Norbert Wiener University, Lima, Peru; maria.rojasr@uwiener.edu.pe (M.R.R.)
[7]Faculty of engineering. Technological University of Peru; c07160@utp.edu.pe (L.G.J.D.A.)
[8]Professional School of Food Engineering, Faculty of Oceanography, Fisheries, Food Sciences and Aquaculture. National University Federico Villarreal, Lima, Peru; hfuertes@unfv.edu.pe (H.G.F.V.)

Abstract: Objective. Determine was statistical mathematically the percentage (%) of prevalence of childhood caries in children between the ages of one and thirteen years as a function of diet and oral hygiene wearing the Empirical Modeling Theory of Bronstein & Semendiaev. Design. Correlational, predictive and transversal study. Participants. Patients from one year to thirteen years old were considered and distributed in four groups from one to four years old; from five to seven years old, from eight to ten years old and from eleven to thirteen years old; respectively. Twelve children have been considered in each group and we have worked with the average percentage of prevalence of each group; in which each average percentage of prevalence was contrasted with age during eight consecutive years. Main measurement. Each dispersogram showed that the first and third groups have similar behavior (sigmoidal or logistic) and groups two and four showed different behavior to groups one and three, but similar behavior between them (quadratic). Results. The statistical-mathematical analysis for groups one and three turned out tobe good, with coefficients of determination of r^2=0,9752 and r^2=0,9347respectively, and the relationship between time t(years) and the percentage (%) of prevalence of childhood caries (P), for children between 1 and 4 years old and 8 to 10 years old is real, there is a non-significant difference, the predictive models have high estimation, there is a "*very strong correlation*" between the elapsed time (t) and the percentage (%) of prevalence of childhood caries (P).Conclusions. The statistical-mathematical analysis for groups two and four proved to be good, with coefficients of determination of r^2=0,9595 and r^2=0,8562. respectively, and the relationship between time, t(years) and the percentage (%) of prevalence of childhood caries (P), for children between five and seven years and eleven to thirteen years, is real, there is a non-significant difference, the predictive models have high estimation, there is a "*very strong correlation*" between the elapsed time (t) and the percentage (%) prevalence of childhood caries (P).

Keywords: *Childhood caries, Prevalence, Statistical-mathematical analysis.*

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* Correspondence: omarin@unfv.edu.pe

1. Introduction

Nino, et al. [1] tells us that oral diseases caused by oral hygiene are a major problem in our country, as more than 80 % of school-aged children are affected. Zotti, et al. [2] tells us that oral diseases can cause severe pain and tooth loss, which affect appearance, dietary intake and, consequently, the growth and development of children.

Castillo, et al. [3] tell us that early childhood caries is a worldwide oral health problem, and Peru is one of the countries with high prevalence of early childhood caries, where the risk factors are poverty, high sugar consumption and low oral health literacy, in which oral health has not received high public health priority in Perú.

Caries affects the upper primary incisors and primary first molars in a manner that reflects the eruption pattern and the longer the tooth has been present and exposed to caries challenge, the more affected it has been found to be and the upper incisors are the most vulnerable, while the mandibular incisors are protected by the tongue and saliva from the submandibular and sublingual glands [4].

Dental caries is an infectious and progressive disease, which begins in areas of demineralization, caused by bacterial metabolic acids, manifested by "white spots", but more pronounced in children 2 to 5 years (92 %), with the consequences of inflammation, which if not treated promptly, the carious lesion will continue to destroy the tooth, and eventually cause pain, infection water, local and systemic infections, compromising various organs such as ears, kidneys, joints and heart; causing tooth loss which in turn alters the normal function of the masticatory system, the digestive system and to the family economy, conditions that affect the health and quality of life of the population, that with early intervention, dental caries can be prevented or treated at a reduced cost [5].

Fluoride is a valuable caries prevention modality that has a large amount of evidence for its use; due to the fact that infants, young children, and their parents often visit the dentist. Fluoride is very effective in preventing dental caries with both primary and secondary preventive properties [6].

Bernal, et al. [7] tells us that initial caries lesions, or also called "white spot" are those that affect the vestibular surfaces of the incisors, presence of opaque white demineralization in some areas, with an intact surface where the subsurface lesion is reversible, and these lesions occur shortly after tooth eruption.

Bernal, et al. [7] tells us that cavitated lesions occur in periods from 6 months to the first year, presenting yellowish coloration of soft consistency with extension towards the palatal and proximal areas that, when they remain untreated, the patient adopts a more adequate diet or improves dental control, the lesions can become dark coloration and hardened consistency and occur after tooth eruption.

Bernal, et al. [7] mention that lesions with pulp tissue involvement present multiple, extensive lesions and destruction of the crown, pulp involvement and root remnants.

In Perú, dental caries has been recognized as a public health problem strongly related to the consumption of sugars in the diet, which raises a concern in the field of food safety; addressing percentages of 85 to 95 % in adolescent children, among its many risk factors, inadequate oral hygiene, presence of microorganisms in the oral cavity and to the consumption of highly cardiogenic diet, lack of knowledge of oral health care and great disinterest in oral health care [4].

Castillo, et al. [3] tell us that brushing teeth at least twice a day with fluoride-containing toothpaste is considered an important aspect of prevention and promotion of good brushing habits at an early age to prevent dental caries in early childhood.

The Ministry of Health [8] argues that inadequate oral hygiene and the use of toothpaste with insufficient fluoride condition is the presence of dental caries in 85 % of children under 11 years of age. Schmoeckel, et al. [9] argue that sugar has received significant attention in public health in recent years, recommending that the ideal consumption of added sugars should be no more than 5 % of total daily energy intake.

Tinanoff, et al. [10] argue state that the highest risk of dental caries was found among children who brushed once a day or less and by the number of foods containing high values of sugars in their daily diet. Skafida and Chambers [6] showed that food consumption is significantly associated with dental caries. They argue that children are more likely to have dental caries from the age of 5 years if they consume high-sugar soft drinks, candies, chocolates, etc. Compared to children who at 2 years of age ate mainly healthy foods, fruits, were less prone to dental caries.

EsSalud [11] affirms that the number of children with caries is increasing day by day, each time at younger ages, the causes they claim to be inadequate and incorrect oral hygiene, use of toothpaste with a low concentration of fluoride, and an inadequate diet and without oral hygiene, reaching up to 95 %. EsSalud recommends avoiding foods such as sweets, chocolates, use of toothpaste with fluoride (1000 ppm for children from 1 to 3 years, 1500 ppm between 3 to 6 years), brushing teeth after ingesting any candy or sugary drink, and a control before the first year in a specialist.

The Ministry of Health Pasco [12] indicates that in departments such as Pasco, Puno and Apurimac are the regions with the highest prevalence of dental caries in children aged 3 to 15 years, with figures exceeding 98%, the causes are inadequate oral hygiene and no control on teeth; mainly.

The Ministry of Health Pasco [12] argues that, in Perú, there is a technical standard that recommends the use of toothpaste with the concentration of 1000-1500 ppm of fluoride in toothbrushing under parental supervision, which should be performed at least 2 times a day.

2. Methods

Methodology. For the percentage (%) of prevalence of childhood caries in children from 1 to 4 years old and from 8 to 10 years old; we have based ourselves on figures 1 and 3 that describe a logistic behavior, based on the specific constant of growth (k), where the conditions of the process will exert restrictions on, bearing in mind that the constant (k) will decrease as the percentage (%) of prevalence of child caries increases and assuming that this k (grows or decreases) only depends on the number of children with child caries and not on time-dependent mechanisms, such as non-seasonal phenomena; arriving to determine a logistic equation whose solution is a logistic function. Considering that a mathematical model is a mathematical description often by means of a function or equation of a real-world phenomenon, such as the percentage (%) of prevalence of childhood caries in children; whose purpose is to understand the prevalence of caries in children and why not to make predictions regarding future behavior. The stages covered were: 1) the problem of modeling the percentage (%) prevalence of childhood caries in children, 2) formulating and choosing, through data dispersion, the logistic model, 3) determining the model for each event (childhood caries in children from 1 to 4 years old and from 8 to 10 years old and 4) making predictions (estimates) about the percentage (%) prevalence of childhood caries. Keeping in mind that the mathematical model is never a completely accurate representation, that it is only an idealization; it simplifies the mathematical model enough to promote valuable conclusions and relevant discussions. For the percentage (%) prevalence of childhood caries in children aged 5 to 7 years and 11 to 13 years; we have relied on Figures 2 and 4; where the behavior is polynomial of degree 2, of the form P (%) $=A+B\times t+C\times t^2$

Processediment. It has been determined that the percentage (%) of prevalence of childhood caries in children aged 1 to 4 years and 8 to 10 years describe a logistic dispersion of type $N=\frac{M}{1+Q\times e^{k\times t}}$ (1); where "$\boldsymbol{M}$" is a maximum quantity of the percentage (%) prevalence of childhood caries, "$\boldsymbol{Q}$" a pre-exponential quantity, "$\boldsymbol{k}$" constant of proportionality, "$\boldsymbol{t}$" is elapsed time (years) and "$\boldsymbol{P}$" is the percentage (%) of prevalence of childhood caries, as the case may be. The procedure is as follows:

1) To determine the mathematical model for estimating the behavior of the percentage (%) prevalence of childhood caries in children, we relied on the Empirical Modeling theory of Bronshtein and K. [13].
2) The way to calculate $\boldsymbol{M}$for the three events is to consider three independent random values and their corresponding database dependent values, using the formula: $M=\frac{A\times B-I^2}{A+B-2I}$…(2)
3) The first value ($\boldsymbol{A}$) is the value of the dependent variable, which corresponds to the independent variable (t_1); this value being the one at which the behavior presents an inflection point (value very close to the half of the last data of the dependent variable), the second value ($\boldsymbol{B}$) will be the value of the dependent variable that corresponds to the last data of the independent variable (t_2)

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and the third value (***I***), is the value of the dependent variable that corresponds to the semisum of the independent variables t_1 y t_2; denoted as: $t_3=(t_1+t_2)/2$.

4) The determined value of M is replaced in the logistic model.
5) The logistic model is mathematically linearized, to which we apply the method of least squares, adopting the form: $\ln\left(\frac{M}{N}-1\right)=lnQ+k\times t$; which is a linear equation: $y=A+Cx$; where $y=\ln\left(\frac{M}{N}-1\right)$, $x=t$ and $A=lnQ$.
6) The statistical process of linear regression can be performed on a computer or scientific calculator, by entering the ordered pairs (x, y) data of the form: $\left[\,t,\ln\left(\frac{M}{N}-1\right)\,\right]$, which, having entered all ordered pairs, we look for the values lnQ and k.
7) The value of k is the value of the slope of the linear equation, i.e. the value "C"value of the linear equation: y=A+Cx; the value of A is lnB and, therefore $Q=e^{A}$.
8) In the same linear regression process, we evaluated the correlation statistic, Pearson'**s** $\boldsymbol{r}$ Pearson's correlation statistic.
9) With all these parameters, the logistic model is determined.

For the percentage (%) of prevalence of childhood caries in children aged 5 to 7 years and 11 to 13 years, a second-degree polynomial regression was performed, obtaining the following parameters A, B, C, r (correlation coefficient) and $r2$(determination coefficient).

Statistical treatment. Hernández [14] mention that the statistical treatment of correlated data; to determine the validity of the models and the correlation and determination coefficients, the significance test of the Pearson correlation coefficient should be performed. $\boldsymbol{r}$ Pearson's correlation coefficient, in which it is desired to know if the value of $\boldsymbol{r}$ represents a real relationship between the two variables. The standard error of r should be calculated using the expression:

$$t_c=\frac{|r|}{\sqrt{1-r^2}}\times\sqrt{N-2}\ldots(3)$$

Comparing the $\boldsymbol{t}$ Student's (t_{cal}) and the table (t_{tab}); the relationship between elapsed time (years) and prevalence (%) of childhood caries in children will be concluded, $\boldsymbol{t}$ (years) and the prevalence (%) of childhood caries in children, the estimation of the predictive models and the interpretation of the correlation coefficients ($\boldsymbol{r}$) and determination ($\boldsymbol{r^2}$) of the two predictive models.

Materials. The data were obtained from EsSalud [11] carefully arranged chronologically**,** grouped into four age groups and each group was made up of twelve children: group one from 1 to 4 years, group two from 5 to 7 years, group three from 8 to 10 years and group 11 to 13 years. When data dispersion was performed, groups one and three followed a logistic dispersion and groups two and four followed a polynomial dispersion of degree two. The data were compiled for the last seven years, measuring prevalence (%) and estimated prevalence as a function of elapsed time, t, (years); presented in tables 1, 2, 3 and 4.

3. Results

Applying the methodology and procedure indicated, the data treatment for the four (4) age groups is shown below:

Logistic analysis of childhood caries: first group (children 1 to 4 years of age).

First value: $t_1=2\ years$, corresponds to: A=34,49 %

Second value: $t_2=7\ years$, corresponds to: B=38,15 %

Third value: $t_3=\frac{2+7}{2}=4{,}5\ years$, corresponds to: I=37,08 %

Now, we replace in (2): $M=\frac{34{,}49\times38{,}15-37{,}08^2}{34{,}49+38{,}15-2(37{,}08)}=38{,}9032\ \%$

The model $N=\frac{M}{1+B\times e^{k\times t}}$ can be written $\widehat{N}=\frac{38{,}9032}{1+B\times e^{k\times t}}$

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Applying the method of least squares to the expression $\ln\left(\frac{38,9032}{N}-1\right)=B+k\times t$; obtain the prediction or estimation model.

$\widehat{N}=\frac{38,9032}{1+0,20664\times e^{-0,32963\times t}}\ldots(4)$

With a correlation coefficient r=−0,9875 and coefficient of determination of r^2=0,9752

Logistic analysis of childhood caries: third group (children 8 to 10 years old).

First value: $t_1=3\ years,$ corresponds to: A=73,92 %

Second value: $t_2=7\ years,$ corresponds to: B=75,40 %

Third value: $t_3=\frac{3+7}{2}=5\ years$, corresponds to: I=74,92 %

Now, we replace in (2): $M=\frac{73,92\times 75,40-74,92^2}{73,92+75,40-2(74,92)}=76,5516\ \%$

The model $N=\frac{M}{1+B\times e^{k\times t}}$ can be written $\widehat{N}=\frac{76,5516}{1+B\times e^{k\times t}}$

Applying the method of least squares to the expression $\ln\left(\frac{75,5516}{N}-1\right)=B+k\times t$; obtain the prediction or estimation model.

$\widehat{N}=\frac{75,5516}{1+0,07404\times e^{-0,252514\times t}}\ldots(5)$

With a correlation coefficient r=−0,9668 and coefficient of determination of r^2=0,9347

Table 1.
Percentage (%) prevalence and percentage (%) estimated prevalence of childhood caries in children aged 1 to 4 years.

Time (t). years	Prevalence. P (%)	$\widehat{\text{Prevalence}}.\ P$(%)
0	33.41	32.24
1	33.62	33.88
2	34.49	35.15
3	35.94	36.13
4	36.81	36.87
5	37.32	37.42
6	37.95	37.82
7	38.15	38.12

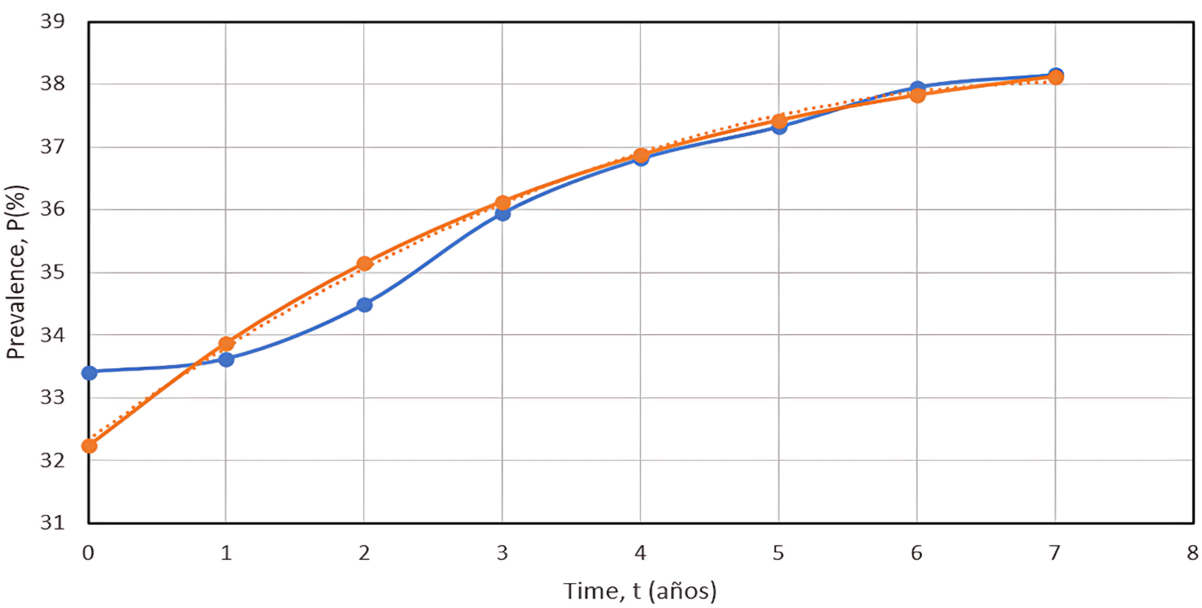

Figure 1.
Percentage (%) prevalence and percentage (%) estimated prevalence of childhood caries in children from 1 to 4 years of age.

Table 2.
Percentage (%) prevalence and percentage (%) estimated prevalence of childhood caries in children 8 to 10 years of age.

Time (t). years	Prevalence. P (%)	$\widehat{\text{Prevalence}}. P(\%)$
0	71.82	71.27
1	72.05	72.39
2	72.50	73.28
3	73.92	73.98
4	75.10	74.54
5	74.92	74.28
6	75.30	75.33
7	75.54	75.60

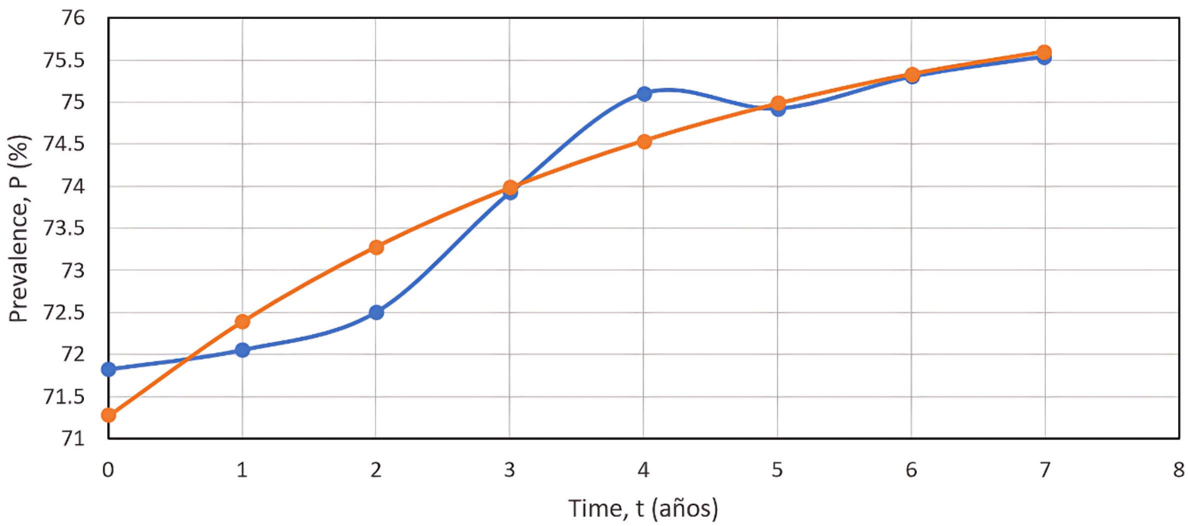

Figure 2.
Percentage (%) prevalence and percentage (%) estimated prevalence of childhood caries in children aged 8 to 10 years, as a function of time t (years).

3.1. Regression Analysis, Childhood Caries: Second Group (Children Aged 5 to 7 years)

The percentage (%) prevalence of childhood caries in children aged 5 to 7 years was determined to be of the form: P (%) $=A+B\times t+C\times t^2$; where the model determined was: $P(\%) = 51{,}98 + 9{,}1854 \times t - 1{,}3096 \times t^2 \ldots$ (6), with correlation coefficient $r=-0{,}9795$ and coefficient of determination of $r^2=0{,}9595$.

3.2. Regression Analysis, Childhood Caries: Fourth Group (Children Aged 11 to 13 years

The percentage (%) of prevalence of childhood caries in children aged 11 to 13 years, has been determined to be of the form: P (%) $=A+B\times t+C\times t^2$... (7); where the model determined was: P (%) $=53{,}015+1{,}8339\times t-0{,}2634\times t^2$... (7); where the model determined was: with correlation coefficient $r=-0{,}9253$ and coefficient of determination of $r^2=0{,}8562$.

Table 3.
Percentage (%) prevalence and percentage (%) estimated prevalence of childhood caries in children aged 5 to 7 years.

Time (t), years	Prevalence, P (%)	$\widehat{\text{Prevalence}}, P(\%)$
0	52,02	51,98
1	58,52	59,86
2	66,05	65,14
3	69,65	67,81
4	67,70	67,87
5	65,05	65,34
6	57,20	60,20
7	54,48	52,45

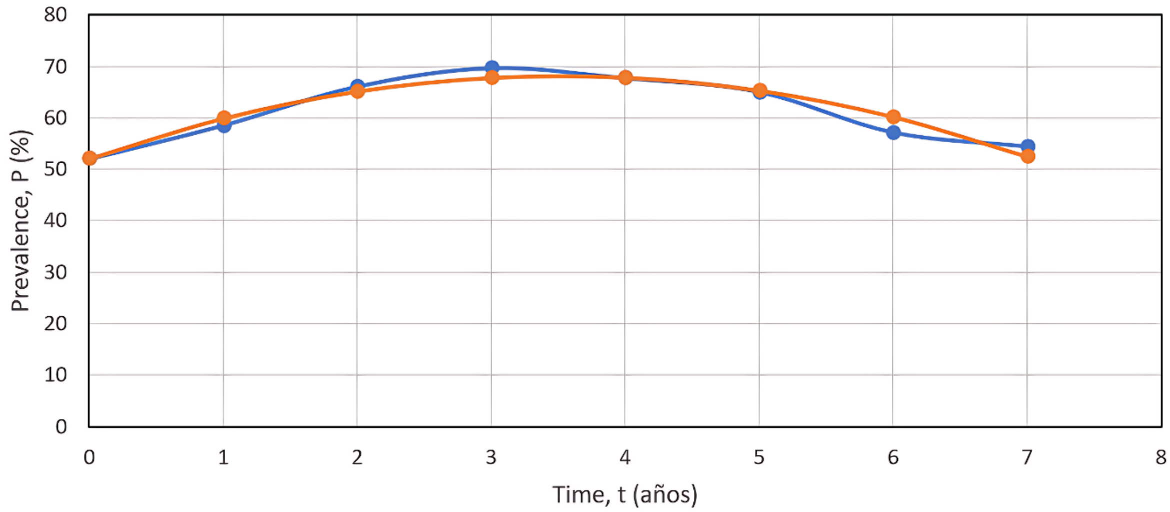

Figure 3.
Percentage (%) prevalence and percentage (%) estimated prevalence of childhood caries in children aged 5 to 7 years, as a function of time t (years).

Table 4.
Percentage (%) prevalence and percentage (%) estimated prevalence of childhood caries in children 11 to 13 years old.

Time (t), years	Prevalence, P (%)	$\widehat{\text{Prevalence}}, P(\%)$
0	53,74	53,02
1	53,85	54,58
2	55,10	55,63
3	56,00	56,15
4	56,62	56,14
5	56,10	55,60
6	54,64	54,54
7	52,54	52,95

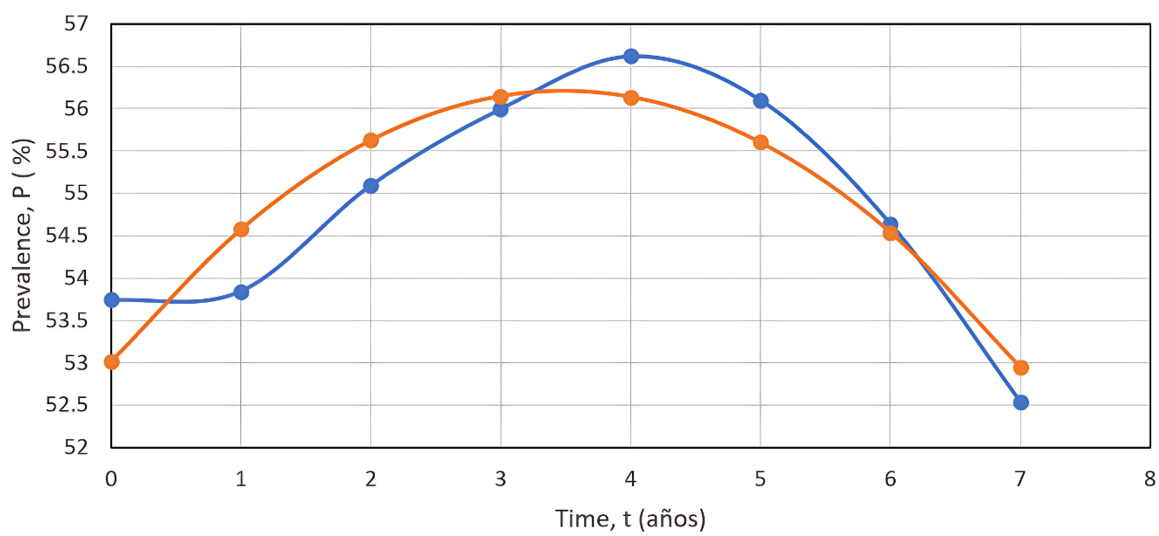

Figure 4.
Percentage (%) prevalence and percentage (%) estimated prevalence of childhood caries in children aged 11 to 13 years, as a function of time t (years).

Significance test of r. Pearson's correlation coefficient "r" of Pearson between the percentage (%) prevalence of childhood caries and the elapsed time t, (years) was performed for the four groups:

1. For children between 1 and 4 years of age, it was r=−0,9875where the standard error of "r" was calculated using expression (3):

$$t_c = \frac{|-0{,}9875|}{\sqrt{1-(-0{,}9875)^2}} \times \sqrt{8-2} = 15{,}3463 \quad \text{and} \quad t_{t(8;0{,}95)} = 1{,}86$$

Interpretation: as $t_{cal} = 15{,}3463$ is greater than $t_{tab} = 1{,}86$; it is concluded that the relationship between time, t(years) and the percentage (%) of prevalence of childhood caries (P), for children between 1 and 4 years old, is real; therefore, there is a non-significant difference, the predictive model has a high estimation of the correlated data, there is a "*very strong correlation*" between the elapsed time (t) and the percentage (%) prevalence of childhood caries (P) and 97,52 % of the variance in P is explained by $t$for the percentage (%) prevalence of childhood caries.

2. For children aged 5 to 7 years it was r=−0,97954 where the standard error of "r" was calculated using the expression (3):

$$t_c = \frac{|-0{,}97954|}{\sqrt{1-(-0{,}97954)^2}} \times \sqrt{8-2} = 11{,}9224 \quad \text{and} \quad t_{t(8;0{,}95)} = 1{,}86$$

Interpretation: as $t_{cal} = 11{,}9224$ is greater than $t_{tab} = 1{,}86$; it is concluded that the relationship between time, t(years) and the percentage (%) of prevalence of childhood caries (P), for children between 5 and 7 years old, is real; therefore, there is a non-significant difference, the predictive model has a high estimation of the correlated data, there is a "*very strong correlation*" between the elapsed time (t) and the percentage (%) prevalence of childhood caries (P) and 95,95 % of the variance in P is explained by $t$for the percentage (%) prevalence of childhood caries.

3. For children between 8 and 10 years of age it was r=−0,9668where the standard error of "r" was calculated using the expression (3):

$$t_c = \frac{|-0{,}9668|}{\sqrt{1-(-0{,}9668)^2}} \times \sqrt{8-2} = 9{,}2675 \quad \text{and} \quad t_{t(8;0{,}95)} = 1{,}86$$

Interpretation: as $t_{cal} = 9{,}2675$ is greater than $t_{tab} = 1{,}86$; it is concluded that the relationship between time, t(years) and the percentage (%) of prevalence of childhood caries (P), for children between 8 to 10 years old, is real; therefore, there is a non-significant difference, the predictive model has a high estimation of the correlated data, there is a "*very strong correlation*" between the elapsed time (t) and the percentage (%) prevalence of childhood caries (P), and 92.04 % of the variance in P is explained by $t$for the percentage (%) prevalence of childhood caries.

4. For children aged 11 to 13 years it was r=−0,9253where the standard error of "r" was calculated using the expression (3):

$$t_c = \frac{|-0{,}9253|}{\sqrt{1-(-0{,}9253)^2}} \times \sqrt{8-2} = 5{,}9765 \quad \text{and} \quad t_{t(8;0{,}95)} = 1{,}86$$

Interpretation: as $t_{cal} = 5{,}9765$ is greater than $t_{tab} = 1{,}86$; it is concluded that the relationship between time, t(years) and the percentage (%) of prevalence of childhood caries (P), for children between 11 and 13 years old, is real; therefore, there is a non-significant difference, the predictive model has a high estimation of the correlated data, there is a "*very strong correlation*" between the elapsed time (t) and the percentage(%) prevalence of childhood caries (P) and 85,61 % of the variance in P is explained by $t$for the percentage (%) prevalence of childhood caries.

4. Discussion

The logistic estimation of the percentage (%) of prevalence for childhood caries in children aged 1 to 4 years and 8 to 10 years showed, in both cases, that it is very high, reaching values of correlation and determination coefficients of r=−0,9875 and $r^2 = 0{,}9752$; and $r = -0{,}9668$ and $r^2 = 0{,}9347$; respectively, coinciding with that reported by Nino, et al. [1], Morales Miranda and Gómez Gonzáles [5] and Ministry of Health [8]. The polynomial estimation of the percentage (%) prevalence of

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childhood caries, for children aged 5 to 7 years and 11 to 13 years; showed, in both cases, that it is very high, reaching values of correlation and determination coefficients of $r= -0{,}9795$ y $r^2 = 0{,}9594$; y $r = -0{,}9253$ y $r^2 = 0{,}8562$; respectively, coinciding with that mentioned by Seow [4], EsSalud [11] and Ministry of Health [8].

It is also concluded that, statistically,the significance of the Pearson's correlation coefficient "r"1) For children between 1 and 4 years of age, it is concluded that the relationship between time (years) and percentage (%) of prevalence of childhood caries and the time elapsed t, (years),for the four groups was as follows: 1) For children between 1 and 4 years of age, it is concluded that the relationship between time, t(years) and the percentage (%) of prevalence of childhood caries (P), is real; therefore, there is a non-significant difference, the predictive model has high estimation of the correlated data, there is a "*very strong correlation*" between the elapsed time (t) and the percentage (%) prevalence of childhood caries (P) and 97,52 % of the variance in P is explained by t1) for the percentage (%) prevalence of childhood caries. 2) For children between 5 and 7 it is concluded that the relationship between time, t(years) and the percentage (%) prevalence of childhood caries (P), for children between 5 to 7 years old, is real; therefore, there is a non-significant difference, the predictive model has a high estimation of the correlated data, there is a "*very strong correlation*" between the time elapsed (t) and the percentage (%) prevalence of childhood caries (P) and 95,95 % of the variance in P is explained by $t$for the percentage (%) prevalence of childhood caries. 3) For children between 8 and 10 years of age, it is concluded that the relationship between time, t(years) and the percentage (%) prevalence of childhood caries (P), for children between 8 to 10 years old, is real; therefore, there is a non-significant difference, the predictive model has a high estimation of the correlated data, there is a "*very strong correlation*" between the elapsed time (t) and the percentage (%) prevalence of childhood caries (P), and 92,04 % of the variance in P is explained by t4) For children between 11 and 13 years of age, it is concluded that the relationship between the time (years) and the percentage (%) of prevalence of childhood caries (P) and the percentage (%) of prevalence of childhood caries (P), t(years) and the percentage (%) prevalence of childhood caries (P), for children between 11 to 13 years old, is real; therefore, there is a non-significant difference, the predictive model has a high estimation of the correlated data, there is a "*very strong correlation*" between the elapsed time (t) and the percentage (%) prevalence of childhood caries (P) and 85,61% of the variance in P is explained by $t$for the percentage (%) prevalence of childhood caries. As for the most important recommendations, it can be suggested to take into account in the educational part for pregnant mothers and children in the stage from 1 to 5 years of age to emphasize good hygiene, a diet low in sugars; as a preventive complement and to train and encourage the use of hygiene elements such as brushes, toothpaste, pit and fissure sealants and fluoridation in the preschool stage so that the teeth have healthyeruptions and, above all, in good positions.

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