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Prolonged exclusive lactation and low educational level of mothers as potential risk factors for the occurrence of iron deficiency anemia among young Algerian preschool children living in poor rural area (Djelfa)

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Abstract.
BACKGROUND AND OBJECTIVES: In Algeria, iron deficiency anemia is a major public health problem. A descriptive cross-sectional study was carried out to assess the prevalence of anemia and iron deficiency anemia and to investigate the factors associated with iron deficiency anemia.
MATERIALS AND METHODS: A total of 368 clinically healthy children aged between 6 months and 5years living in a poor rural area of Algeria were assessed in this study. Biological indicators of iron status were assayed, and those of malnutrition were calculated. Socio-economic and dietary data were also collected.
RESULTS: The prevalence of iron deficiency anemia was 20.92% (95%CI: 17–25%), accounting for 86.5% of anemia cases. Nutritional components appeared as a potential cause of its occurrence. Binary logistic regression demonstrated that this elevated frequency is significantly correlated with risk factors relating to infancy(<2 years) (OR = 2.68 [95CI%: 1.47–4.97]),late introduction of weaning foods (OR = 2.51 [95%CI:1.29–5.05]), exclusive lactation(OR = 3.22 [95%CI:1.37–7.6]), low educational level of mothers (OR = 3.42 [95% CI: 1.52–7.65]) and gender (boys) (OR = 2.39 [95% CI:1.39–4.39]).
CONCLUSIONS: Anemia and iron deficiency anemia were significant health problems among the studied sample. The improvement of the socio-economic status of mothers and weaning practices should both be included in public health strategies for the control and prevention of iron deficiency anemia in our population.

Keywords: Iron deficiency anemia, anemia, preschool children, Algeria, rural area

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1. Introduction

Iron deficiency anemia (IDA) is considered the most widespread dietary disorder in the world [1], affecting approximately 30% of the world's population [2]. Preschool children and pregnant women constitute the most vulnerable community because of their important physiological needs linked to growth and gestation respectively [3–6]. Iron deficiency is the major cause of anemia [7], during which irreversible alterations of neurocognitive functions and growth retardation may occur in children [8].

Generally, the prevalence of anemia and IDA among preschool children is estimated at 47.4% and 27% worldwide, respectively, with African countries and Southeast Asia recording the highest frequencies [9].

In 2011, according to WHO estimations, more than three out of ten Algerian preschool children were affected by anemia [10, 11]. The nutritional component, particularly the low bioavailability of iron in the Algerian diet, remains the main cause of this disorder [12]. There are several disparities in terms of infrastructure and care access between urban and poor rural sectors in Algeria [12], contributing to the particular vulnerability of rural populations, especially preschool children, to certain disorders such as anemia and IDA [13, 14].The dimensions of the problem have not been well defined, and few studies using reliable biochemical indicators have been performed to assess the iron status of Algerian children. Indeed, the prevalence of iron deficiency anemia and its associated factors remain largely unknown in many rural sectors of the country. We believe that the effectiveness of any strategic public health program to fight iron deficiency and IDA in preschool children must be based on knowledge of the prevalence and risk factors associated with these anomalies. Therefore, the aim of the current study was to determine the current prevalence of anemia and IDA and to investigate the possible socio-economic and nutritional risk factors associated with IDA among preschool children living in a poor rural area of Algeria.

2. Materials and methods

2.1. Location and population of the study

Our study was undertaken between June 2013 and January 2015 at the pediatric ward of the health center of the municipality of El Idrissia (southwest of Algiers). Sheep farming is the main economic activity in this area. A total of 368 children, aged between 6 months and 5 years, all seen for a vaccination pattern, were selected for the survey. On the basis of a 42.5% prevalence of anemia in Algerian preschool children [9], the prevalence of IDA (P) is estimated at approximately 40%. For sample size calculation, power was determined in the study as equal to 0.8 and alpha (α) was equal to 0.05 (as in a previous study [15]). Our estimation for the sample size was as follows:

$$\mathrm{N} = \mathrm{Z}^2 x\, P\, x\, \frac{(1-p)}{D^2} \quad ; \ \mathrm{N} = (1.96)^2\ x\, 0.4\, x\, \frac{(1-0.4)}{0.05^2} = 368$$

where N is *the required sample size, Z is the standard deviation with a 95% confidence interval, P is the estimated prevalence, and D is the 5% absolute precision.*

The criteria for inclusion of children in this study were as follows: apparently healthy (confirmed by clinical examination), lack of medical and surgical history, no blood transfusion during the 12 months preceding the survey day and non-administration of any treatment with iron, folic acid or vitamin B12.

2.2. Ethics and data collection

The study was approved by the scientific council of the National High School of Agronomy of Algiers. The study was validated by the pediatric ward of the health center of the municipality of El Idrissia and conforms to the guidelines of the World Medical Association Declaration of Helsinki (2000). Verbal parental consent was obtained, witnessed and formally recorded for all study participants prior to enrollment. A questionnaire was developed to collect data on several risk factors associated with increased frequency of iron deficiency anemia in children in accordance with previously conducted surveys. The investigated factors were age, gender, level of maternal education, parental income, spacing between pregnancy of the selected child and the preceding offspring, mother's age, family size, birth weight, dietary data such as the type and duration of lactation, weaning age and the nature of daily consumed foods. The definitions of exclusive breastfeeding and age of introduction of weaning foods are in accordance with World Health Organization (WHO) definitions [16]. The type and frequency of daily consumed foods were investigated using a five-step multiple-pass five dietary repeated 24 hour recall method [17], where in mothers were asked to remember all foods eaten by their children during 3 non-successive days (one of the three days recorded included one weekend day) following the day of vaccination. The average of all three 24 h dietary recalls was used as a representation of individual intake. The mean of dietary iron intake was calculated using Diet Analysis Program, 1995 (Lifestyles Technologies, Inc., Northbridge Point, Valencia, California) supplemented by the African [18] and Tunisian food composition table [19] and then compared to the recommended daily allowance (RDA) according to the infant's age [20].

2.3. Anthropometric data

For each child, we conducted measurements of weight and height, which were used to calculate their BMI. Weight measurements were performed using an electronic scale (SECA881, GMBH, Germany) with a maximum range of 200 Kg. Height was measured using a mobile measuring mat for children under 24 months (SECA210, GMBH, and Germany) and a stadiometer for older children. Each measurement was carried out in accordance with the standards and recommendations of the anthropometric measurements guide [21]. The data obtained were entered and subsequently converted into z-scores using the software Anthropo Plus OMS (V.1.0.4). Underweight was considered present if the child had a z-score (weight for age) less than 2 standard deviations from that of the reference population (WZA<-2SD), while stunting was considered present only if the z-score of height for age was less than 2 standard deviations (HZA<-2SD). Overweight was considered present if the z-score of BMI for age was more than 2 standard deviations away from the reference population (ZBMIA>+2SD) [22]. For corpulence, we considered the BMI to be normal if it was between the 3rd and the 97th percentile [22]. The weight at birth was deemed low if it was less than or equal to 2.5 kg [23].

2.4. Sampling, hematology and inflammatory data

All children included in this study underwent an assessment of their iron status and characterization of their inflammatory status. To this end, approximately 9 to 10 mL of venous blood was collected in the morning (around 10 am) by a qualified laboratory technician at the polyclinic of El Idrissia. This sample was obtained at the crease of the elbow of each child and divided equally between two 5 mL tubes: one contained ethylene diamine tetra acetic acid (EDTA), whilst the other was dry. The EDTA-containing tube was used to determine the blood count using a hematological counter (ERMA PCE-210, Erma Inc. Japan) at the laboratory of the polyclinic of El Idrissia. The latter tube was used to obtain serum by centrifugation for 5 min at 3200 rpm. The recovered serum was stored at –20°C and subsequently used for the determination of serum iron biochemical parameters (serum iron [SI] using a colorimetric method [24], serum transferrin [Trsf] and serum ferritin [Ft] were assayed by immunoturbidimetric testing [25], and inflammation (C-reactive protein [CRP] was assayed by agglutination [26]) using a Cobas Integra 400 Plus biochemistry automaton). Using the serum iron and transferrin data, we calculated the total capacity for the binding of iron by transferrin (TIBC) and the saturation coefficient (TS) using the following formulas:

$$\mathbf{TIBC}\left(\frac{\mu\text{mol}}{\text{L}}\right) = Tranferrin\ \left(\frac{g}{L}\right) x\, 25,1\, [27]\,;\ \mathbf{TS}\ (\ \%\ ) = \frac{Sarum\ iron\ \left(\frac{\mu\ \text{mol}}{\text{L}}\right)}{TIBC\ \left(\frac{\mu\text{mol}}{\text{L}}\right)} x\, 100\ [28]\,.$$

Anemia was defined as a hemoglobin (Hb) threshold $\leq$11 g/dL and the following thresholds were used to define its intensity: severe anemia (Hb < 7 g/dL), moderate anemia (7 $\leq$ Hb $\leq$ 9.9 g/dL), and mild anemia (10 $\leq$ Hb < 11 g/dL) [29]. Microcytosis was defined as a mean corpuscular volume rate (MCV) <75 fL [30], while mean corpuscular hemoglobin (MCH) <27 pg defined hypochromia [31]. The total depletion of iron stores was defined as ferritin levels less than 12 µg/L (Ft < 12 µg/L) and less than 30 µg/L when inflammation was considered present [32], while a low coefficient of transferrin saturation (TS < 16%) [33, 34] with completely depleted iron stores Ft < 12 µg/L was used to identify iron deficiency. In addition, iron deficiency anemia was considered present if the hemoglobin level in children with iron deficiency was low (Ft < 12 µg/L+ST<16%+Hb<11 g/dL). Inflammation was considered present when CRP levels were higher or equal to 5 mg/L [35].

2.5. Statistical analysis

Statistical analysis was performed using software (SPSS, version 19 Statistics, IBM, USA). Normal distribution of the variables was determined using the Kolmogorov-Smirnov test. Normally distributed data are given in means and standard deviations, whereas non-normally distributed data are depicted in medians and interquartile ranges. For data comparison of two independent samples, we employed the Mann-Whitney test and *t*-test for non-normally distributed and normally distributed data, respectively. The Chi-square test was used to identify the relationship between independent variables. In addition, the degree of association between quantitative variables was analyzed with the nonparametric correlation Spearman rank test. Finally, we used binary logistic regression to predict the risk factors associated with an increase in the occurrence of iron deficiency anemia with a 95% confidence interval (CI = 95%) and a significance level of $p \leq 0.05$.

3. Results

3.1. Descriptive and socio-demographic study of the sample

This study included 368 children (192 boys [52.17%] and 176 girls [47.82%]), all aged between 6 months and 5 years, with a median age of 25 $\pm$ 5 months. The median age of the boys was 22 $\pm$ 5 months, whilst that of the girls was 25 $\pm$ 1 month. The analysis of socio-economic conditions of parents revealed that the majority of children were selected from a humble background, with over 96% of mothers being housewives and nearly half (44.02%) of fathers practicing sheep farming. Educational attainment remained low, with more than 78.53% of mothers not having completed high school. On the basis of collected data, the income of more than 43% of the parents did not exceed the minimum wage in the country (approximately 7 US $ per day). The mothers' age ranged between 21 and 48 years. Only 29% of them were primiparous, and the average spacing between pregnancy of the child selected and the preceding offspring was 21.90 $\pm$ 9 months. The average parity was 2.75 $\pm$ 1.6 children, and almost a quarter of the children had not been followed by medical teams since fetal age. Vaccination coverage was satisfactory, as 88.43% of the children were vaccinated (Table 1).

3.2. Dietary data

The analysis of dietary data showed that 34 children (9.23%) in the study were still breastfeeding or bottle feeding. These children consisted of 5 children who were exclusively breastfed, 18 who were exclusively given infant formula, 3 who were both breastfed and given formula milk, and 8 who were exclusively fed powdered

Table 1
Descriptive and socio-economic characteristics of the study sample

Age	Number	%
6–11 months	58	15.76
12–23 months	89	24.18
24–35 months	79	21.46
36–47 months	68	18.47
48–60 months	74	20.1
Gender		
Boys	192	52.17
Girls	176	47.82
Family size		
2–5 members	251	68.2
5–8 members	99	26.9
>8 members	18	4.89
Mother’s educational level		
Low < 6 academic years	71	19.29
Medium 6–12 academic years	207	59.23
High->12 academic years	90	21.46
Parental income		
Low (≤7 US $/day)	161	43.75
Low or High >7 US $/ day	207	56.25
Mother’s work		
Working mothers	12	3.26
House wives	354	96.19
Father’s work		
Sheep farming	162	44.02
Traders	92	25
Salaried	114	30.97

whole milk. The average weaning age was 5.2 ± 2.37 months. Late withdrawal remained common, with 67 children (18.02% [95%CI: 14–22%]) being weaned late.

Cereals, fruits, vegetable-based preparations, and dairy products were the foods most widely consumed by the children. Only 19 (5.68%) of them were found not to consume meat or meat-based food products. The average coverage of the daily iron intake in our sample was estimated at $67 \pm 39\%$ of the recommended dietary allowance (RDA), the coverage was estimated at less than 50% of RDA in 102 children, between 50 and 75% of RDA in 110 children and more than 75% of RDA in 156 children.

3.3. Birth weight and frequency of malnutrition

The analysis of anthropometric data showed that 336 children (91.3% [95%CI: 88.1–93.7%]) had normal corpulence (3rd percentile≤BMI<97th percentile). Low birth weight was found to be infrequent, with only 41 children (11.4% [95%CI: 8–14%) having been born with a weight of less than or equal to 2.5 kg. No significant differences were observed between girls and boys in terms of weight or height.

Analysis of the z-score values suggested that stunting (HAZ<-2SD) and overweight (BMIAZ>+2SD) were the prevalent forms of malnutrition in the sample, at 19.29% (95%CI: 15.24–23.34%) and 7.34% (95%CI:

4.66–10%), respectively. In contrast, only 4.34% (95%CI: 2–6%) of the children were found to be underweight (WAZ<-2SD). Moreover, sharp growth retardation (HAZ<-3SD) and obesity (BMIAZ>+3SD) were seen in 1.63% (95%CI: 0.3–2.33%) and 1.09% (95%CI:0.2–2.15%) of the children, respectively.

3.4. Prevalence of anemia, IDA and the factors associated with IDA

Analysis of the distribution of biological parameters relating to iron status revealed that the hemoglobin data followed a normal distribution. In contrast, the Kolmogorov-Smirnov test showed that the distributions of all other parameters were significantly different from a Gaussian distribution ($p \leq 0.05$). The average hemoglobin of all children was 11.89 ± 1.45 g/dL. The median values of the other parameters were as follows: ferritin: 27.21 ± 18.27 μg/L; TRSF: 2.22 ± 0.35 g/L; TS: 28.16 ± 9.66%; TIBC: 55.5 ± 8.69%; MCV: 82.1 ± 3.38 fL; MCH: 28.04 ± 1.21 pg. Table 2 shows the distribution of biological parameters of iron status and the mean iron intake of children according to investigated risk factors.

Our results show that 89 children (24.18% [95%CI: 19.79–28.28%]) met the criteria for anemia. These children were found to have an average hemoglobin level of 9.99 ± 0.81 g/dL (95%CI: 9.82–10.16%), 54 (60.64%) of them were less than 24 months old, and 62 (69.66%) were boys (Table 3).

The intensity of anemia was deemed mild to moderate, as 56 children (62.92%) with mild anemia had an average hemoglobin level of 10.54 ± 0.27 g/dL (95%CI: 10.47–10.62%), whilst 33 (37.07%) of the rest were moderately anemic, with an average hemoglobin level of 9.09 ± 0.58 g/dL (95%CI: 8.88–9.29%). The MCV and MCH values showed that 60 children (16.3% [95%CI: 12.51–20.1%]) had microcytosis (MCV < 75 fL), with a median MCV of 73.74 ± 2.8 fL, whilst 18.2% of the children (95%CI: 14.25–22.17%) had hypochromia (MCH < 27 pg), with a median MCH of 25.16 ± 1.21 pg. Hypo chromic microcytic anemia was the most common form, with 53 anemic children (59.55%) presenting this type. This was followed by 34.83% of anemic children having the normochromic normocytic type, and the normocytic hypochromic type was present in the remaining 5.62%.

Correlative study of the ranks of biological indicators of iron status showed significant positive correlations between the values of hemoglobin and those of red blood cell (RBC) indices: (MCV-Hb: $r = 0.857$; Hb-MCH: $r = 0.785$; $p < 0.01$). Ferritin correlated less strongly with hemoglobin levels ($r = 0.535$; $p < 0.05$) and with those of serum iron ($r = 0.511$). Notably, there were trends for negative correlations between transferrin levels and ferritin ($r = –0.62$), MCH ($r = –0.61$), and hemoglobin ($r = –0.62$), whilst transferrin levels showed negative correlations with TS ($r = –0.79$) and MCV ($r = –0.64$). In addition, we observed significant positive correlations between the mean daily iron intake and the levels of serum iron ($r = 0.23$), ferritin ($r = 0.13$) hemoglobin ($r = 0.22$) and mother's education ($r = 0.105$). However, the latter variable was correlated negatively with the transferrin levels ($r = –0.09$) (Table 4).

The analysis of ferritin levels showed that 130 children (35.05% [95%CI: 30–40%]) in our sample had completely depleted iron stores (Ft < 12 μg/L). Their mean ferritin level was 10.61 ± 1.43 μg/L (95%CI: 10.37–10.87%). Among them, 78 children (60.46%) met the criteria for iron deficiency (Ft < 12 μg/L+TS<16%), of whom 77 (98.71%) had anemia (Ft < 12 μg/L+TS<16%+Hb<11 g/dL). Five children amongst the 89 anemic children met the criteria for inflammatory anemia (Hb < 11 g/dL+CRP>5 mg/L). Their average CRP was found to be 56.28 ± 18.97 mg/L, and 2 of them suffered from depleted iron stores. However, the other 7 anemic children had anemia with poorly identified origins.

Significant differences in the values of hemoglobin were observed between boys and girls as well as between children aged under two years and older children (Table 2). While the prevalence of iron deficiency anemia itself was estimated at 20.92% (95%CI: 17–25%) (Table 3), it remained significantly higher for boys than for girls (OR = 2.24 [95%CI: 1.32–3.81] and it gradually decreased with age (OR = 2.12 [95%CI: 1.24–3.5]).

Despite an average daily iron intake more than 50% of RDA, children who were weaned after the first 6 months of life are more affected by IDA than those who were weaned before this period (Table 2). Whatever

Table 2
Distribution of mean iron intake and biological parameters of iron status according to investigated risk factors

	N (%)	FS (μg/L) Median ± IQR)	IS (μmol/L) Median ± (IQR)	HB (μg/dL) (Mean ± SD)	TS (%) (Median ± IQR)	Iron intake (% of RDA Median ± IQR)
Total	**368 (100)**	**27.18 ± 18.2**	**14.19 ± 3.72**	**11.89 ± 1.45**	**28.16 ± 9.66**	**67 ± 39**
Gender						
Boys	192(52.17)	26,36 ± 18.7	14.29 ± 4.53	11.98 ± 1.9^{T*}	28.03 ± 14.7^{U*}	65 ± 38
Girls	176(47.88)	27.94 ± 17.9	15.04 ± 2.63	11.99 ± 1.67	28.19 ± 2.29	71.5 ± 50.5
Age						
<24 months	147(39.94)	25.04 ± 20.4^{U*}	14.23 ± 4.75	11.8 ± 1.93^{T*}	28 ± 14.87	65 ± 40
≥24 months	221(60.05)	27.2 ± 17.5	15.07 ± 2.72	12.02 ± 1.69	28.19 ± 2.59	69 ± 41.5
ME						
Low or Medium†	278(75.54)	26.92 ± 17.8	14.78 ± 4.14	11.89 ± 1.86	28.16 ± 10.3	65 ± 37.9
High	90(24.45)	27.75 ± 21.3	14.8 ± 3.02	12 ± 1.86	28.13 ± 9.02	69.3 ± 40
PI						
Low‡	161(43.75)	27.22 ± 20.5	14.64 ± 3.24	12 ± 1.71	28.2 ± 14.6	65.3 ± 37
Medium or High	207(56.25)	27.2 ± 17.25	14.86 ± 4.19	11.67 ± 1.86	28.14 ± 4.9	67 ± 40.4
Mother's age						
>30 years	213(57.88)	27.2 ± 20.31	14.57 ± 3.57	12.01 ± 1.79	28.13 ± 3.7	64.9 ± 38
≤30 years	155(42.11)	27.34 ± 17.2	14.92 ± 3.89	11.76 ± 1.86	28.19 ± 14.6	67.1 ± 40
Underweight						
(WAZ <2SD)	16(4.34)	27.2 ± 18.25^{U*}	14.91 ± 3.68	10.3 ± 1.01^{T*}	14.21 ± 1.24	51.5 ± 26
(WAZ>-2SD)	352(95.65)	30 ± 36	13.44 ± 2.83	11.97 ± 1.73	18.17 ± 4.93	69 ± 37.75
Stunting						
(HAZ<-2SD)	72(19.56)	28.29 ± 18.3^{U*}	14.82 ± 3.8	12.18 ± 1.55	27.62 ± 14.49	81 ± 81
(HAZ>-2SD)	296(80.43)	27.2 ± 18.3	14.92 ± 3.5	11.92 ± 1.77	28.19 ± 4.25	67 ± 39
Overweight						
(BMIZ>+2SD)	27(7.33)	27.2 ± 18.26	14.84 ± 3.75	11.91 ± 1.76	29.10 ± 1.95	65 ± 49
(BMIZ<+2SD)	341(92.66)	27.56 ± 19.1	14.18 ± 3.84	12.08 ± 1.3	29.09 ± 10.29	67.1 ± 39
VC						
Incomplete	44(11.95)	27.91 ± 1.39	14.88 ± 3.03	11,91 ± 1.22	28.18 ± 2.51	65.2 ± 39
Complete	324(88.08)	27.23 ± 18.33	14.82 ± 3.92	11.90 ± 1.77	28.12 ± 13.38	72 ± 36
Exclusive lactation	34(9.23)	26.2 ± 18.15^{U*}	13.17 ± 4.84	11.02 ± 1.7^{T*}	14.5 ± 14.14	51 ± 35.7^{U*}
Weaned children	334(90.76)	27.23 ± 18.2	14.93 ± 3.25	12 ± 1.66	28.19 ± 2.77	71.4 ± 39
Exclusively breastfed	5(1.35)	11 ± 1.16	10.19 ± 2.61	10.12 ± 0.87	13.99 ± 3.65	46 ± 58.5
F.E. on infant formula	18(4.89)	20.13 ± 28.73	13.46 ± 3.99	11.31 ± 1.36	14.65 ± 14	55 ± 44.75
F.E. on breast milk+infant formula)	3(0.81)	10.85	11.17	10.67 ± 1.45	14.7	52
F.E. on whole powder milk	8(2.61)	38 ± 39.96	14.89 ± 3.44	11.07 ± 1.98	14.51 ± 14.8	51.5 ± 19.5
Weaning age						
>6 months	67(18.2)	27.11 ± 17.2	14.97 ± 3.03	11.1 ± 1.94^{T*}	23.83 ± 14.27	60 ± 42
<6 months	301(81.79)	27.43 ± 18.18	14.23 ± 5.18	12.01 ± 1.68	28.19 ± 2.68	71 ± 39.5
S.B.P.						
<18 months	186(50.4)	27.63 ± 19	14.49 ± 3.43	11.58 ± 1.8^{T*}	28.29 ± 14.8	68.5 ± 40.5
>18 months	182(49.3)	24.12 ± 22.17	14.95 ± 4.05	12 ± 1.7	28.06 ± 6.35	65 ± 38.5

(*Continued*)

Table 2
(*Continued*)

	N (%)	FS (µg/L) Median ± IQR)	IS (µmol/L) Median ± (IQR)	HB (µg/dL) (Mean ± SD)	TS (%) (Median ± IQR)	Iron intake (% of RDA Median ± IQR)
Birth weight						
<2.5 kg	41(11.14)	30,95 ± 25	14.46 ± 5.37	11.88 ± 1.5	23.86 ± 16.35	63 ± 30.2
>2.5 kg	327(88.85)	27.07 ± 17.6	14.84 ± 3.4	11.9 ± 1.35	28.17 ± 3.46	69.5 ± 39.9
Pregnancy						
Care Regular	279(75.81)	27.11 ± 18.5	14.18 ± 3.28	11.93 ± 1.39	28.11 ± 6.18	64.9 ± 38
Irregular	89(24.18)	27.2 ± 18.26	14.98 ± 3.92	11.88 ± 1.48	28.17 ± 14.47	72 ± 36
Family size						
≤8 members	350(95.1)	27.42 ± 18.34	14.85 ± 3.48	11.90 ± 1.46	28.16 ± 8.81	65.5 ± 40[U*]
>8 members	18(4.9)	18.66 ± 16.81	14.22 ± 4.45	11.73 ± 1.44	27.97 ± 14.2	47.5 ± 47

†: less than 12 academic years; ‡less than 7 US$/day; includes exclusive breast feeding, both breast and/or bottle feeding, fed exclusively on infant formula and fed exclusively on whole milk powder; ME: mother' educational level; PI: parental income; RDA: recommended dietary allowance[14]; VC: vaccination coverage; Hb: hemoglobin level; FS: ferritin serum level; IQR: interquartile; SD: standard deviation; IDA: iron deficiency anemia; F.E: fed exclusively; T*: significant independent Student's t-test (the homogeneity of variance was verified with *Levene's test*); U*: significant Mann-Whitney test; SBP: spacing between pregnancy of the selected child and preceding offspring. BMIZ: Body Mass index for Age z-score; WAZ: weight for age z-score; HAZ: Height for age z-score.

Table 3
Prevalence of anemia and IDA according to age and gender

	Anemia		*P*- Value†	IDA		*P*-Value†
	N	% (CI 95%)		N	% (CI 95%)	
Total (N = 368)	89	24.18 (19,79–24.58)		77	20.92 (17–25%)	
Gender						
Boys (N = 192)	62	32.29 (25.62–38.77)	**0.0001****	52	27.08 (21–33.03)	**0.002****
Girls (N = 176)	27	15.34 (9.96–20.72)		25	14.2 (9.01–19)	
Age						
<24 months (N = 147)	54	36.73 (28.85–44.62)	**0.0001****	43	29.25 (21–36.02)	**0.003****
≥2 4 months (N = 217)	35	16.12 (10.99–20.69)		34	15.66 (11–21.1)	

**:Highly significant. †:*P* value of Chi-squared test. IDA: Iron deficiency anemia. N = Number. CI: Confidence interval.

the type of milk consumed, our results suggest that the prevalence of IDA remains higher among children who were exclusively breastfed or bottle-fed, with 44% [95%CI: 27–62%] IDA compared to that of those who had been introduced to weaning foods, with an IDA prevalence of 19% [95%CI: 15–24%]). The increased frequency of IDA was also significantly related to low educational level of the mother (OR = 1.98 [1.01–3.86]) and to low daily iron intake (OR = 1.8 [1.06–3.07]) (Table 5).

Multivariate analysis was used to assess the effects of the significant explanatory variables to distinguish predictors of IDA, and the results confirmed that the latter was significantly increased if the child was less than 2 years old, weaned late, still exclusively breastfed or bottle fed, if the mother's level of education was low and in boys (Table 6).

Table 4
Correlative study of biological parameters of iron status, mean iron intake and socio-economic data†

	IS	FT	TRSF	Hb	TS	MCV	MCH	Iron intake‡	PI	MI	Family Size
IS	1	0.51**	–0.49**	0.73**	0.842**	0.719**	0.656**	0.234**	0.042	0.114*	–0.56*
FT		1	–0.62**	0.535**	0.43**	0.543**	0.5**	0.138*	–0.01	0.09	–0.108*
TRSF			1	–0.627**	–0.799**	–0.64**	–0.61**	0.226**	–0.004	–0.095	0.07
HB				1	0.828**	0.857**	0.785**	0.226**	0.038	0.083	–0.034
TS					1	0.676**	0.715**	0.307**	0.046	0.085	–0.07
MCV						1	0.867**	0.243**	–0.019	0.098	–0.008
MCH							1	0.24**	–0.007	0.054	–0.11*
Iron Intake‡								1	0.029	0.105*	–0.088
PI									1	0.219*	–0.036
ME										1	–0.118*
Family Size											1

*Significant ($p < 0.05$); **highly significant ($p < 0.01$). †: correlative test using Spearman correlation; ‡: % of calculated mean of daily iron intake compared to RDA (recommended dietary allowance) [20]; IS: iron serum; Hb: hemoglobin (g/dL); TS: transferrin saturation (%); MCV: mean corpuscular volume (fL); MCH: mean corpuscular hemoglobin (pg); FT: Ferritin level (μg/dL); TRSF: Transferrin level (g/L). ME: mother's educational level (number of academic years); PI: parental income.

Table 5
Univariate analysis of investigated risk factors for IDA in children

	Normal (N = 291) %(CI95%)	IDA (N = 77) %(CI95%)	Crude OR [CI95%]	*P* value
Total (N = 368)	**79.08 (74.9–83)**	**20.92 (17–25)**	–	–
Gender Boys (N = 192)	72.91 (67–79.3)	27.08 (21–33%)	**2.24** (1.32–3.81)	**0.002****
Age<24 months (N = 147)	71.4 (64.04–78.8)	28.57 (21–36)	**2.12** (1.27–3.5)	**0.003****
ME Low or Medium† (N = 278)	76.61 (79.5–93.3)	23.38 (18–28)	**1.98** (1.01–3.86)	**0.04***
PI Low‡ (N = 161)	78.26 (72.59–83)	21.73 (16–27)	1.12 (0, 67–1.86)	0.66
Mothers' age >30 years (N = 213)	77 (71.3–82.69)	23 (17–29)	1.35 (0.8–2.27)	0.25
Underweight (WAZ<-2SD) (N = 16)	75 (51–98.83)	25 (10–49)	1.27 (0.39–4.06)	0.68
Stunting (HAZ<-2SD) (N = 72)	76.38 (66–86.4)	23.6 (13–32)	1.14 (0.67–2.13)	0.67
Overweight (BMIZ>+2SD) (N = 27)	81.49 (74–83.2)	18.51 (17–25)	0.84 (0.31–2.32)	0.75
VC Incomplete (N = 44)	86.37 (73.6–82.6)	13.63 (3–21)	0.56 (0.22–1.38)	0.2
Exclusive lactation§ (N = 34)	55.88 (38.3–73)	44.1 (27–62)	**2.61** (1.24–5.49)	**0.009****
Weaning age >6 months (N = 67)	64.18 (52–75)	35.82 (24–48)	**2.63** (1.46–4.46)	**0.001****
Iron intake <50% of RDA (N = 112)	71.56 (62–80.4)	28.43 (20–37)	**1.8** (1.06–3.07)	**0.028***
SBP<18 months (N = 182)	78.03 (71.9–84)	21.97 (16–28)	1.13 (0.68–1.87)	0.623
Birth weight <2.5 kg (N = 41)	73.17 (58–86.9)	26.8 (13–48)	1.5 (0.71–3.17)	0.279
Pregnancy Care Irregular (N = 89)	78.5 (72.7–89.2)	22 (17–26)	0.86 (0.47–1.57)	0.627
Large family size >8 members (N = 18)	72.2 (49.3–95.14)	27.7 (5–51)	1.48 (0.51–4.3)	0.46

*: Significant ($p < 0.05$). **: Highly significant ($p < 0.01$). †: less than 12 academic years; ‡: less than 7 U$/day; §: exclusive lactation: breast feeding, both breast and/or bottle feeding, fed exclusively on infant formula and fed exclusively on whole milk powder; ME: mother's educational level; PI: parental income; RDA: recommended dietary allowance [20]; VC: vaccination coverage; OR: Odds Ratiov; SD: standard deviation; IDA: iron deficiency anemia; SBP: spacing between pregnancy of the selected child and preceding offspring; HAZ: Height for age z-score; WAZ: weight for age z-score : BMIZ: Body mass index for age z-score; SD : standard deviation. CI: Confidence interval.

Table 6
Multivariate analysis of potential factors for IDA among the investigated children[†,‡]

	Prevalence of IDA			
	Estimated β	EXP (β)	CI 95% for EXP (β)	*P*-value
Variable				
Constant	–3.36	–	–	
Age (<24 months)	0.98	2.68	1.45–4.97	0.002**
Gender (Boys)	0.78	2.39	1.29–4.39	0.005**
Low mother's educational level (Less than 12 academic years)	1.23	3.42	1.52–7.65	0.003**
Exclusive lactation	1.17	3.22	1.37–7.6	0.007**
Late weaning age (>6 months)	0.92	2.51	1.29–5.05	0.011*

*: Significant $P < 0{,}05$; **: highly significant $P < 0{,}01$. †: Variables included in the model were as follows: age, gender, mother's educational level, exclusive lactation, weaning age and mean of daily iron intake. ‡: Multivariate analysis using binary logistic regression. §: Exclusive lactation includes exclusive breastfeeding and/or bottle feeding. IDA: iron deficiency aneamia. β: Estimated parameter. CI: Confidence interval.

4. Discussion

In our study sample, the prevalence of anemia was much lower than in the WHO data in 2008 and those published in the annual report of the Algerian Ministry of Public Health, which estimated frequencies of anemia in the region of 42.5% (95%CI: 14.7–76.1%) among Algerian children preschool age and 38% among school children [9, 36]. However, our findings were slightly higher than the rate obtained in a similar study in 2013 in Sidi Bel Abbes (western Algeria), which recorded an 18% prevalence of anemia in 104 children aged between 3 and 5 years [37]. Our findings were comparable to those obtained by a number of similar surveys conducted in Tunisia [38], Mexico [5], and Cuba [39], where the prevalence of anemia was estimated at 29%, 20% and 26%, respectively. According to Schneider et al., the conditions of the study populations, the biological parameters measured, and the thresholds used may be at the origin of these differences in prevalence [28]. Although no scientific consensus has revealed the involvement of the gender factor in the occurrence of anemia and iron deficiency anemia before puberty, we observed a higher frequency of these disorders in boys than in girls. The same findings were observed in numerous studies [40, 41], where it was explained by the potential influence of the kinetics of iron during the child's first year of life and by weight gain [41, 42].

The mild to moderate intensity of anemia and the absence of severe anemia in our sample are probably attributable to the children's inclusion criteria (clinically healthy) in this study, as a significant contrast exists between mild clinical symptoms and severe anemia [43]. The results of the correlative study of ranks of biological indicators of iron status may explain the strong contribution of iron deficiency to the occurrence of anemia in our sample, which has been broadly supported by several authors [3, 7, 34, 38, 40, 43]. In Africa, a recent study, which explored the health demographics of children from 11 French-speaking countries, suggested that much anemia was due to iron deficiency [44]. Other authors reported that frequencies of 65%, 70.1%, and 88.4% of anemia cases in children were due to iron deficiency [34, 40, 45]. The erythrocyte indicators did not suggest any cases of megaloblastic anemia, characteristic of deficiencies in vitamin B12 and/or folate [46]. Inflammatory syndromes with or without iron deficiency contributed to 5.61% of the anemia. This finding can probably be explained by the fact that these syndromes do not manifest openly and can cause anemia through their involvement in dysfunction of erythropoiesis and increasing the synthesis of hepcidin [7]. Additionally, the absence of a link between anemia and inflammation or iron deficiency in 7 of the 89 anemic children suggests the possible involvement of factors that were not investigated in the current study. Potential factors include vitamin A deficiency, which is essential for erythropoiesis [47], or a quantitative hemoglobinopathy such as β thalassemia.

With respect to anemia, the prevalence of IDA depends mainly on the conditions of the study and/or the population. To our knowledge, very few studies have addressed the prevalence of IDA in children in Algeria, which makes it difficult to compare our results with those obtained in other surveys. However, if we take into consideration certain settings such as those in this study, including the age of children and biological parameters measured, our prevalence remains relatively close to that obtained in a previous investigation, which showed a frequency of 20.31% IDA in Tunisia [38]. Another study in 744 children aged under 5 from an urban area in Tunisia showed an IDA rate of 20.7% [48]. IDA frequencies of 26.7 and 29.1% have also been reported in preschool children of the Marshall Islands Republic [49] and Iran [15], respectively.

Low iron intake may be the most probable factor for the development of IDA [1]. Our results show that the frequency of IDA significantly decreased with age and with high iron intake. Many studies have reported the same findings [40, 45, 49], indicating that at ages younger than 2 years, children are more vulnerable to the risk of developing anemia and IDA because of their requirement for iron during the growing period [50]. Despite an average daily iron intake above 50% of RDA, the high frequency of IDA among children who were weaned late indicated that the introduction of weaning foods had a very slow effect on improving their iron status, which was likely exacerbated by the prolonged exclusive lactation. It must be noted that the potential low iron bioavailability of these foods may also be at the origin of the occurrence of IDA [51].

According to a UNICEF survey, prolonged exclusive lactation is a fairly common practice in Algeria. In particular, the central and coastal areas of Algeria were found to exhibit high rates of breastfeeding after the first 6 months of life [52]. The association between exclusive breastfeeding and iron deficiency during the first year of life has been widely documented in several previous studies [53, 54]. The increased frequency of IDA in children consuming powdered cow's milk, breast milk and infant formula in our study may be explained by the fact that cow's milk, the main constituent of whole milk powder, has low iron bioavailability [55, 56]. This characteristic can result in losses of fecal blood due to allergy to milk proteins. In addition, cow's milk is particularly rich in calcium and casein, which have been shown to significantly inhibit the absorption of non-heme iron in the body [54, 57]. Meanwhile, breast milk remains the best food recommended for children, especially during the first 4 to 6 months of life, due to its composition [40] and its protective effect against diarrhea, pneumonia and infections [56]. However, beyond this period, exclusive breastfeeding constitutes a risk factor for the development of iron deficiency because the iron content of breast milk is inadequate for the child's growth needs [58]. Additionally, it has been reported that the iron content of infant formula milk may be insufficient to support the child's growing requirement for iron if exclusive lactation is prolonged beyond the first 6 months of life [59].

Our study has shown that a child whose mother has a low to medium educated education level at a 3.4-fold increased risk of IDA. In Malaysia, Al-Mekhlafi et al. found an up to 3.9-fold increased risk of IDA in children with poorly educated mothers [35]. A significant association was also reported in South Korea and South Africa between low educational level of mothers and increased prevalence of anemia in children [13, 60]. Various explanations for this pattern include the conventional effects of exclusive breastfeeding practices on the child's health in infancy and the low nutritional value of food ingested by children of mothers with a low educational level [14]. The latter is probably due to ignorance regarding dosage during the preparation of milk, certain cooking methods, and insufficient feeding frequency resulting from the inaccessibility of certain foods.

Contrary to what has been reported by a number of surveys [45, 61, 62], several risk factors such as different forms of malnutrition (underweight, stunting, overweight) and low weight at birth paradoxically did not show any statistically significant associations with IDA in our study, whilst other studies have reported similar observations [4, 38, 66]. This discrepancy suggests that such factors may indirectly affect the iron status of the child, and the latter may be directly related to the low bioavailability of iron from ingested food. Although there was no significant relationship between factors that can influence maternal iron status during pregnancy and the increased frequency of IDA in this study, Paiva et al. in 2007 reported that it is still not clear whether iron deficiency in pregnant women can lead to a deficient iron status in their newborns [65]. Several other authors have supported the hypothesis that iron transport from the mother to her fetus occurs independently of maternal iron levels

[66, 67]. However, further studies are required to shed light on whether maternal iron deficiency can cause depletion of fetal iron stores.

The scope of our current work did not allow for the identification of the definite causes of IDA. Thus, further work is required to establish the underlying factors causing IDA in our study sample. For instance, stool analysis for the presence of parasites or occult blood in stool and further testing such as the assessment of maternal iron status during pregnancy could shed light on the potential causes of IDA. Other poor areas in Algeria should also be surveyed to provide a broader picture of IDA prevalence.

5. Conclusions

In conclusion, this work shows that anemia and IDA remain a serious public health problem in Algerian children from rural areas. This elevated prevalence of IDA was found to be associated with a number of risk factors, including low educational level of mothers, exclusive lactation, and late introduction of weaning foods. From this study, three lines of intervention are suggested in strategic nutritional programs to reduce the prevalence of iron deficiency anemia in children in rural areas of Algeria. Firstly, systematic iron supplementation in early infancy is recommended. Secondly, the socio-economic status and the educational level of mothers should be ameliorated. Thirdly, educational programs for mothers should be implemented to highlight appropriate weaning practices and their impact on the health status of their children.

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Conflicts of interest

None.

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