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Prevalence of anaemia, deficiencies of iron and vitamin A and their determinants in rural women and young children: a cross-sectional study in Kalalé district of northern Benin

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Abstract

Objective: To identify the magnitude of anaemia and deficiencies of Fe (ID) and vitamin A (VAD) and their associated factors among rural women and children.
Design: Cross-sectional, comprising a household, health and nutrition survey and determination of Hb, biochemical (serum concentrations of ferritin, retinol, C-reactive protein and α_1-acid glycoprotein) and anthropometric parameters. Multivariate logistic regression examined associations of various factors with anaemia and micronutrient deficiencies.
Setting: Kalalé district, northern Benin.
Subjects: Mother–child pairs (*n* 767): non-pregnant women of reproductive age (15–49 years) and children 6–59 months old.
Results: In women, the overall prevalence of anaemia, ID, Fe-deficiency anaemia (IDA) and VAD was 47·7, 18·3, 11·3 and 17·7 %, respectively. A similar pattern for anaemia (82·4 %), ID (23·6 %) and IDA (21·2 %) was observed among children, while VAD was greater at 33·6 %. Greater risk of anaemia, ID and VAD was found for low maternal education, maternal farming activity, maternal health status, low food diversity, lack of fruits and vegetables consumption, low protein foods consumption, high infection, anthropometric deficits, large family size, poor sanitary conditions and low socio-economic status. Strong differences were also observed by ethnicity, women's group participation and source of information. Finally, age had a significant effect in children, with those aged 6–23 months having the highest risk for anaemia and those aged 12–23 months at risk for ID and IDA.
Conclusions: Anaemia, ID and VAD were high among rural women and their children in northern Benin, although ID accounted for a small proportion of anaemia. Multicentre studies in various parts of the country are needed to substantiate the present results, so that appropriate and beneficial strategies for micronutrient supplementation and interventions to improve food diversity and quality can be planned.

Keywords
Anaemia
Iron deficiency
Vitamin A deficiency
Women
Children
Benin

Recent reviews of dietary intake data from Benin showed that recommended daily intakes of key micronutrients, such as vitamin A and Fe, were not met[1–4]. At the sub-national level, in northern Benin, macronutrient intakes are also too low[5,6]. Lack of dietary diversity is a particularly severe problem in Benin where diets are based predominantly on starchy staples with little or no animal products and few fresh fruits and vegetables[1,2,7]. According to the last Demographic and Health Survey (DHS) carried out in 2012, only 28 % of rural children satisfied the minimum diversity criterion of eating at least four out of seven food groups and 14 % consumed the minimum acceptable diet. In addition, the prevalence of stunting, wasting and underweight was respectively 40, 5 and 19 % among children aged 6–59 months, while 9 % of rural women had chronic energy deficiency (BMI < 18·5 kg/m^2)[7]. To improve the nutrition situation of women and children in Benin, the Ministry of Health has undertaken several interventions through its Strategic Plan for Food and Nutrition Development, comprising the

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supplementation of three major nutrients (vitamin A, Fe and iodine) and other promotive activities, such as exclusive breast-feeding, appropriate complementary feeding, and improved maternal and child nutrition[8].

Despite the efforts of the line ministry and its stakeholders, Beninese women aged 15–49 years (41 %) and children aged 6–59 months (58 %) are significantly affected by anaemia with greater prevalence in rural areas[7]. Other nutritional data, such as Fe and vitamin A status, however, were not documented in the Benin 2012 DHS. In the 2006 Benin DHS, vitamin A deficiency (VAD) as measured by serum retinol <20 μg/dl was estimated to affect 66·0 % of children aged 12–71 months while the prevalence of night blindness was 11·8 % among pregnant women[9]. The few studies of micronutrient deficiencies among rural populations were conducted in specific localized groups and revealed greater prevalence rates of VAD among 12–71 month-old children (82 %) and pregnant women (14 %) in northern Benin[9], while 33–49 % of children under 5 years of age were Fe deficient[10]. Until now, to our knowledge, there have been no population-based studies permitting generalization about the epidemiology of anaemia and its principal determinants in non-pregnant women, despite the problem being among the top ten causes of morbidities in the country[11,12]. The only study that identified anaemia risk factors among Beninese children was carried out in 2007 and found that incomplete immunization, stunted growth, recent infection, absence of a bednet, low household living standard, low maternal education and low community development index increased the risk of anaemia[13].

As such, identifying the magnitude of anaemia and deficiencies of Fe and vitamin A and their determinants in high-risk groups, such as women of childbearing age and children, is essential for evidence-based intervention modalities, particularly in rural areas, where women and children may suffer not only from micronutrient deficiencies but also a shortage of food[14]. The present study is a very important step forward to avail of evidence-based information on the distribution of anaemia and micronutrient deficits and their predisposing diet and health factors among rural women and children in northern Benin. It will help understand the contemporary health profile of the rural populations of the study area in terms of dietary, socio-economic and environmental factors.

Methods

Location

The study was conducted during the dry season between January and March 2014 in the Kalalé district of northern Benin. The Kalalé district is home to more than 180 000 people, 95 % of whom rely on subsistence farming as their primary means of survival. For most, farming is limited to the rainy season due to a lack of water for irrigation[15]. Prices for basic vegetables (tomatoes, onions, peppers, etc.) almost double during the year from the rainy season to the dry season. The lack of availability and high prices combine to severely limit diets during the dry season and malnutrition is prevalent[16,17].

Study design

Data for the present study were obtained from a baseline survey to evaluate the expansion and implementation of commercial-scale solar-powered drip irrigation systems (solar market gardens, or SMG) that aimed at improving food security, maternal and infant nutrition status, and women's empowerment[18–20]. The cross-sectional study was conducted among sixteen villages. In each village, all households represented in women's groups (WG) were surveyed, along with a random sample of non-women's group (NWG) households from the same village; the goal was to select a maximum of thirty NWG households. In each investigated household, only one mother or caregiver of childbearing age (15–49 years) and her young child (6–59 months of age) were chosen. The first NWG household with a target mother–child in a given geographical area was selected randomly by the village delegate, and the survey continued until the required number of households was covered for each village. If there were more than one woman/child in the house, only one mother–child pair was selected. In total, 774 households were selected from the sampling frame for inclusion in the survey with 770 (311 WG *v.* 459 NWG) successfully recruited. The main reason for non-response was the failure to find individuals at home despite repeated visits to their household. Overall, 767 households were assessed, as three households of pregnant women were excluded from the analyses.

Data collection

Information on socio-economic and demographic characteristics, health status and diet factors was collected, while anthropometric measurements and blood samples were taken from the selected mother–child pairs to assess anaemia, Fe and vitamin A status. Figure 1 describes the study selection process.

Sociodemographic questionnaire

A structured questionnaire was administered to the mother of each participant child and was composed of sociodemographic information (age, education, marital status and family size), obstetric history (pregnancy), illnesses (diarrhoea, malaria and any febrile illnesses in the last 2 weeks) and qualitative dietary information, such as the frequency of consumption of plant- and animal-source foods. The socio-economic status (SES) index was constructed using principal component analysis, and included house and land ownership, housing quality (e.g. house construction materials), access to services (water,

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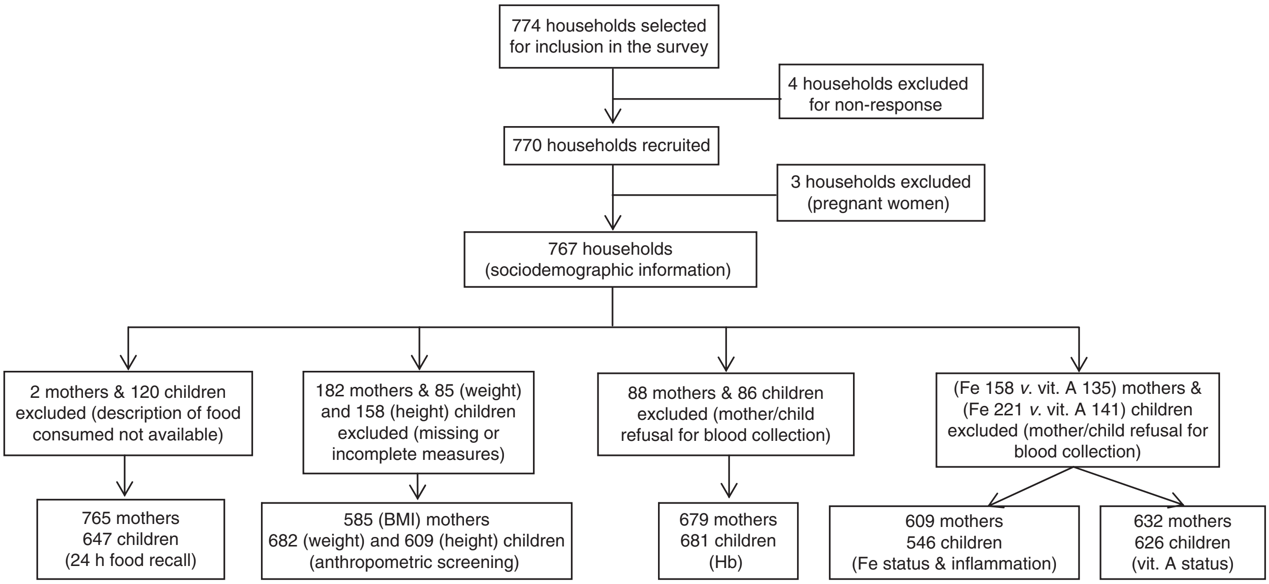

Fig. 1 Study selection process (vit. A, vitamin A)

electricity and gas) and household assets (various durable goods, agricultural machinery, animals and livestock)[21,22]. Factor scores derived from the first factor (which explained 27·8 % of the variance) were then used to characterize the SES of each household. Households were categorized into SES quartiles based on their individual SES index score.

Dietary assessment

A qualitative recall of all foods consumed during the previous 24 h period was performed. Based on the FAO/FANTA Household Dietary Diversity Questionnaire and Guidelines, the dietary data collected were computed into nine food groups for women (starchy staples; dark green leafy vegetables; vitamin-A-rich fruits and vegetables; other fruit and vegetables; organ meat; meat and fish; eggs; legumes, nuts and seeds; milk and milk products) and seven food groups for children (grains, roots and tubers; legumes and nuts; dairy products; flesh foods; eggs; vitamin-A-rich fruits and vegetables; other fruits and vegetables)[23]. The dietary diversity score (DDS) was calculated by summing the number of unique food groups and then divided into tertiles.

Anthropometry

Selected mother–child pairs were invited to come to the village health centre or school early in the morning. Both populations were weighed without shoes or sandals and wearing light clothes using a balance with a precision of 0·1 kg (Body Composition Monitor Scale Tanita BC-543). Height was measured using a device with a precision of 0·1 cm (Shorr Board®). For children under 2 years, measurement of recumbent length was taken on an adjustable child-length measuring board with a precision of 0·1 cm (Shorr Board®). For children aged 6 months to 5 years, anthropometric *Z*-scores were calculated using the National Center for Health Statistics/WHO growth reference data of 2006[24]. Anthropometric status was assessed by the following indicators: weight-for-age *Z*-score <-2 for underweight; height-for-age *Z*-score <-2 for stunting; and weight-for-height *Z*-score <-2 for wasting. For women, BMI was calculated as body weight (in kilograms) divided by the square of height (in metres). Women were classified using BMI cut-off points endorsed by WHO as underweight (BMI < 18·5 kg/m^2), normal (BMI = 18·5–24·9 kg/m^2), overweight (BMI ≥ 25·0 kg/m^2) and obese (BMI ≥ 30·0 kg/m^2)[25].

Blood sampling and analysis

Just after anthropometry, venous blood (2 ml for women and 1 ml for children) was drawn by venepuncture into a sterile tube (no anticoagulant) by a licensed medical technician. Hb was measured immediately using the Hemocue 201® device according to the manufacturer's instructions. Five free-falling drops of blood were collected on a pre-coded special chromatography filter paper (Whatman) and dried in the shade. The dried blood spots were protected from light and stored in a plastic bag with desiccant, and the packaged dried blood spots were preserved in a refrigerator (2–8°C). Then, the packaged dried blood spots were inserted into a rip-resistant envelope and sent by courier within 3 weeks to Craft Technologies, Inc. (Wilson, NC, USA), where retinol levels of the dried blood spots were estimated by the HPLC method[26,27]. The remainder of the blood sample was stored in a cool box and transported at a temperature of 4–8°C. Within 24 h of sample collection, serum was obtained by centrifugation at 3000***g*** for 10 min, then aliquoted into 0·2 ml pre-labelled PCR tubes (Sarstedt) and kept frozen at −20°C before being sent (within 3 weeks) on dry ice to VitMin Lab

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(Willstaett, Germany) for analysis of ferritin (SF), soluble transferrin receptor, body Fe stores, retinol-binding protein, C-reactive protein (CRP) and α_1-acid glycoprotein (AGP) concentrations using a sensible sandwich ELISA technique.

Anaemia was defined according to WHO standards as Hb below 11 mg/dl for children aged 6 months to 5 years and below 12 mg/dl for non-pregnant women[26]. Subclinical inflammation was defined as CRP > 5 mg/l and/or AGP > 1 g/l. Four groups were defined based on CRP and AGP levels: (i) reference (normal CRP and AGP); (ii) incubation (raised CRP and normal AGP); (iii) early convalescence (raised CRP and AGP); and (iv) late convalescence (normal CRP and raised AGP). Corrected values of SF and retinol within inflammation groups were obtained by multiplying values by their respective group corrector factors: SF by 0·77 (incubation), 0·53 (early convalescence) and 0·75 (late convalescence); retinol by 1·13 (incubation), 1·24 (early convalescence) and 1·11 (late convalescence). For children 6–59 months, Fe deficiency (ID) was defined as SF < 12 mg/l for the reference group, SF < 15 mg/l for the incubation group and early convalescence group, and SF < 22 mg/l for the late convalescence group. As for non-pregnant women, ID was defined as SF < 15 mg/l for the reference group, SF < 19 mg/l for the incubation group and early convalescence group, and SF < 27 mg/l for the late convalescence group. Fe-deficiency anaemia (IDA) was defined as the combination of anaemia and ID[28,29]. Subclinical VAD was defined using WHO cut-offs as serum retinol <20 µg/dl for both populations[28,30,31].

Statistical analysis

All statistical analyses were performed using the Stata statistical software package version 14 and statistical significance was set at $P<0{\cdot}05$. To summarize data, categorical variables were expressed as percentages while continuous variables were expressed as arithmetic means, with the exception of SF, as the data were not normally distributed. SF concentrations were log-transformed before statistical analysis. Because of the high proportion of missing data for anaemia, ID, IDA and VAD (12–30 %), missing value analysis (using logistic regression and *t* test) was conducted and revealed that outcome data were missing completely at random. Multivariable logistic regression models for anaemia and micronutrient deficiencies were obtained by using a manual backward stepwise procedure. Age, sex and setting, considered biologically and statistically relevant, and all variables associated with each of the outcomes at the $P<0{\cdot}20$ level were included. At the individual level, in addition to biological variables, factors representing supplements, DDS and infections were included. Consumption of protein (meat, egg, fish or cheese) foods per week and monthly frequency of fruits and vegetables consumption were also used as indicators of diet quality, as they were highly correlated with micronutrient intakes and were a key source of bioavailable forms of Fe and vitamin A. The underlying factors included household ethnicity, maternal education, maternal occupation, family size, access to health care, source of water and hygienic latrine use. SES, food insecurity and source of information were also considered. The major assumptions of logistic regression analysis (absence of multicollinearity and interaction among independent variables) were checked to be satisfied. The goodness of fit was assessed using the Hosmer–Lemeshow statistic. The adjusted odds ratio (AOR) and 95 % confidence interval were computed.

Results

Sociodemographic characteristics

Of the 767 mother–child pairs surveyed, food records were analysed for 765 mothers and 647 children, while anthropometric measurements were collected from 585 mothers, and weight and height were respectively collected from 682 and 609 children. Among the children, 48·9 % were male, mean age was 21·6 months and 50·9 % were under 2 years of age (Table 1). About 65·4 % of the children had received vitamin A supplements in the last 6 months and the children consumed an average 3 pieces of protein foods per week. The mean DDS was 3·1 (out of 7) food groups, while 39·8, 23·6 and 10·9 % of the children were stunted, underweight and wasted, respectively. As for women, the majority had no formal education (90·3 %) and most were aged 30–49 years. Their main occupation was farming and the mean consumption of protein foods was 6 pieces per week. The women's mean DDS was 3·9 (out of 9) food groups and their mean BMI was 22·2 kg/m^2. Among households, mean household size was 7·7 members and a majority was Muslim (92·1 %). About 21·1 % of households were food insecure and 33·0 % had no access to health care, whereas only 13·2 and 8·2 % had access to hygienic latrines and electricity connection, respectively. About 40 % of households consumed fruits and vegetables two or three times per month. The highest ethnic group was Gando (34·5 %) followed by Boo (23·9 %) and other ethnic groups (Peulh, Boko, and Bariba). The main source of information was radio (3·37 d/week).

Anaemia, iron and vitamin A status of mothers and children

Anaemia was present in 47·7 % of women while their prevalence of ID was 18·3 %, with 11·3 % of them classified as having IDA (Table 2). The prevalence of VAD was also high, affecting 17·7 % of surveyed women. As for inflammation status, 3·1 % had elevated CRP only, 14·0 % elevated AGP only, and 5·1 % had elevated CRP and AGP. Anaemia affected more than three-quarters

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Table 1 Characteristics of children, their mothers/caregivers and their households; Kalalé district, northern Benin, January–March 2014

	n	Mean or prevalence	SEM or SEP
Child characteristics			
Age (months)	764	21·59	0·45
Sex, male (%)	764	48·95	1·81
Vitamin A supplements (%)	751	65·38	1·60
Consumed protein foods per week*	702	3·33	0·13
DDS	647	3·10	0·08
Child anthropometry (%)			
Wasting	585	10·94	1·29
Underweight	639	23·63	1·68
Stunting	593	39·80	2·01
Mother/caregiver characteristics			
Age (years)	764	29·86	0·24
Mother's education (%)			
No formal education	755	90·33	1·08
Primary or less		4·37	0·74
Secondary		5·03	0·80
University and more		0·26	0·19
Mother's occupation† (%)			
Agricultural/other labour	759	50·07	1·82
Service/business		16·86	1·36
Others		33·07	1·71
Consumed protein foods* by female adults per week	727	6·01	0·13
DDS	765	3·87	0·05
BMI (kg/m^2)	585	22·19	0·13
Household characteristics			
Household size	764	7·74	0·14
Religion (%)			
Muslim	767	92·12	0·98
Others		7·88	0·98
Ethnicity (%)			
Gando	762	34·51	1·72
Boo		23·88	1·54
Peulh		15·49	1·31
Boko		11·81	1·17
Bariba		10·37	1·10
Others		3·94	0·70
Frequency of fruits and vegetables consumption (%)			
Never	752	11·70	1·17
Several times per month		39·23	1·78
Once or twice per week		29·65	1·67
Almost every day		19·41	1·44
Health and sanitation (%)			
Latrine	742	13·21	1·24
Safe source of water‡	757	65·13	1·73
Electricity connection (%)	747	8·17	1·00
Food insecurity (%)	754	21·09	1·49
Health-care insecurity (%)	740	32·97	1·73
Source of information (d/week)			
Radio	752	3·37	0·11
Television	753	0·42	0·05

SEM, standard error of the mean; SEP, standard of error of the prevalence; DDS, dietary diversity score.
*Protein foods included meat, egg, fish and cheese.
†Agricultural/other labour = farming, livestock and hunting; services/business = small commerce, services, salaried employees and manual workers; others = students and unemployed/retired.
‡Safe source of water included water from a tap and other sources that were treated.

(82·4 %) of the children (Table 3). Their prevalence of ID and IDA was respectively 23·6 and 21·2 %. One-third of children had VAD, while 38·9 % had evidence of suboptimal biochemical status for both micronutrients. The children's prevalence of infection was also high: elevated CRP 1·6 %, elevated AGP 29·8 %, and elevated CRP and AGP 21·2 %.

Table 2 Vitamin A and iron status indicators and prevalence of deficiencies among non-pregnant women of reproductive age; Kalalé district, northern Benin, January–March 2014

	n	Mean or prevalence	SEM or SEP
Hb (mg/dl)	679	11·81	0·05
Hb < 8 mg/dl (%)	679	0·74	0·29
Fe status			
Anaemia* (%)	679	47·72	1·92
SF (μg/l)	609	61·15	1·56
SF < 30 μg/l (%)	609	17·41	1·54
BIS (mg/kg)	609	5·83	0·11
BIS < 0 mg/kg (%)	609	3·78	0·77
sTfR (mg/l)	609	7·47	0·12
sTfR > 8·3 mg/l (%)	609	23·97	1·73
ID† (%)	609	18·29	1·57
IDA‡ (%)	609	11·33	1·28
Vitamin A status			
Serum retinol (μg/dl)	632	31·36	0·53
VAD§ (%)	632	17·72	1·52
Inflammation‖			
CRP (mg/l)	609	1·96	0·23
AGP (g/l)	609	0·81	0·01
Elevated CRP only (%)	609	3·12	0·70
Elevated AGP only (%)		13·96	1·40
Elevated CRP and AGP (%)		5·09	0·89

SEM, standard error of the mean; SEP, standard of error of the prevalence; SF, serum ferritin; BIS, body Fe stores; sTfR, soluble transferrin receptor; ID, Fe deficiency; IDA, Fe-deficiency anaemia; VAD, vitamin A deficiency; CRP, C-reactive protein; AGP, α_1-acid glycoprotein.
*Anaemia defined as Hb < 12 mg/dl.
†ID defined as SF < 15 mg/l (with AGP and CRP normal), <19 mg/l (with raised CRP), <19 mg/l (with raised AGP), <27 mg/l (with raised AGP and CRP) and using corresponding correction factors for SF concentration.
‡IDA defined as ID deficiency and Hb < 12 mg/dl.
§VAD defined as serum retinol <20 μg/dl (with serum retinol concentrations corrected where infection existed).
‖Elevated CRP (CRP > 5 mg/l) and elevated AGP (AGP > 1 g/l).

Associated factors of anaemia and deficiencies of iron and vitamin A in mothers

Logistic regression analysis (Table 4) revealed that infected and low-SES women had respectively 2·0 and 1·8 times greater risk of anaemia diagnosis ($P < 0·05$). However, overweight showed a protective effect (AOR = 0·46; 95 % CI 0·24, 0·88). On the other hand, significantly greater risk of ID was found for low DDS (AOR = 2·13), low BMI (AOR = 5·48), low fruits and vegetables consumption (AOR = 4·12) and low frequency of listening to the radio (AOR = 2·12), as well as in the Boo ethnic group (AOR = 3·01) and households without a latrine (AOR = 2·68). However, women's involvement in business/service was negatively associated with maternal ID (AOR = 0·20; CI 0·03, 0·95). Similar patterns of associations were also observed between the risk of IDA and maternal occupation, infection, and low fruits and vegetables consumption. However, women from large family size (AOR = 4·02) had a significantly greater risk of IDA while women 30–39 years of age (AOR = 0·40) had a significantly lower

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Table 3 Vitamin A and iron status indicators and prevalence of deficiencies among children aged 6–59 months; Kalalé district, northern Benin, January–March 2014

	n	Mean or prevalence	SEM or SEP
Hb (mg/dl)	681	9·49	0·06
Hb <7 mg/dl (%)	681	5·87	0·90
Fe status			
Anaemia* (%)	681	82·38	1·46
SF (μg/l)	546	52·73	2·12
SF < 30 μg/l (%)	546	39·01	2·09
BIS (mg/kg)	546	2·86	0·17
BIS < 0 mg/kg (%)	546	22·89	1·80
sTfR (mg/l)	546	11·22	0·22
sTfR > 8·3 mg/l (%)	546	67·40	2·01
ID† (%)	546	23·63	1·82
IDA‡ (%)	542	21·22	1·76
Vitamin A status			
Serum retinol (μg/dl)	626	21·87	0·33
VAD§ (%)	626	33·55	1·88
Inflammation‖			
CRP (mg/l)	543	4·30	0·35
AGP (g/l)	546	1·07	0·02
Elevated CRP only (%)	543	1·65	0·54
Elevated AGP only (%)	546	29·83	1·96
Elevated CRP and AGP (%)	543	21·18	1·75

SEM, standard error of the mean; SEP, standard of error of the prevalence; SF, serum ferritin; BIS, body Fe stores; sTfR, soluble transferrin receptor; ID, Fe deficiency; IDA, Fe-deficiency anaemia; VAD, vitamin A deficiency; CRP, C-reactive protein; AGP, α_1-acid glycoprotein.
*Anaemia defined as Hb < 11 mg/dl.
†ID defined as SF < 12 mg/l (with AGP and CRP normal), <15 mg/l (with raised CRP), <15 mg/l (with raised AGP), <22 mg/l (with raised AGP and CRP) and using corresponding correction factors for SF concentration.
‡IDA defined as ID deficiency and Hb < 11 mg/dl.
§VAD defined as serum retinol <20 μg/dl (with serum retinol concentrations corrected where infection existed).
‖Elevated CRP (CRP > 5 mg/l) and elevated AGP (AGP > 1 g/l).

risk of IDA. As for maternal VAD, the major determinants identified were lack of education (AOR = 3·89), lack of fruits and vegetables consumption (AOR = 2·72), low consumption of protein foods (AOR = 2·54) and low frequency of radio listening (AOR = 1·40). However, high BMI (AOR = 0·26; CI 0·07, 0·92) and some ethnicities (Boo, Boko and Bariba) showed a significant protective effect. Interestingly, women with ID had a significantly greater risk of VAD (AOR = 1·60; CI 0·13, 4·30).

Associated factors of anaemia and deficiencies of iron and vitamin A in children

With regard to household characteristics, the risk of presenting anaemia among children was significantly greater with untreated water consumption (AOR = 2·18) and low frequency of radio listening (AOR = 2·15; Table 5). Children were more prone to have ID in households with low SES (AOR = 2·89), low frequency of radio listening (AOR = 3·46) and large size of five or more residents (AOR = 2·79), whereas significantly greater risk of VAD was observed among NWG children (AOR = 2·88; CI 1·03, 6·25). Among the maternal variables, children of underweight mothers presented a greater risk of ID (AOR = 4·06; 95 % CI 1·31, 12·62) and IDA (AOR = 5·31; 95 % CI 1·40, 20·14) than children of mothers with normal weight. Children of farming mothers had a significantly greater risk of anaemia (AOR = 2·42; 95 % CI 1·12, 5·22), ID (AOR = 2·26; 95 % CI 1·06, 4·78) and IDA (AOR = 4·60; 95 % CI 1·67, 12·62) compared with children of retired/student women, and children of 30–39-year-old mothers had greater anaemia risk (AOR = 1·47) compared with children of younger women. Interestingly, children whose mothers had anaemia, IDA or VAD had equal significantly greater risk of deficiencies (AOR = 2·42, 2·85 and 3·42, respectively). As for child characteristics, younger age (6–23 months) corresponded with a significantly greater risk of anaemia diagnosis, whereas 12–23-month-old children had higher risk of ID (AOR = 1·39; 95 % CI 1·17, 5·21) and IDA (AOR = 1·67; 95 % CI 1·05, 4·93). The prevalence of ID (AOR = 2·17) and IDA (AOR = 2·16) was also significantly increased among stunted children, whereas low child DDS resulted in greater prevalence of anaemia (AOR = 2·51; 95 % CI 1·08, 5·86) and VAD (AOR = 4·19; 95 % CI 1·52, 11·56). Finally, the occurrence of ID, IDA and VAD was significantly greater among children with infections (AOR = 3·48, 1·85 and 3·12, respectively).

Discussion

The present study showed that, according to the WHO classification[28], the prevalence of anaemia was a severe public health problem in both women of reproductive age and their children aged 6–59 months (>40 %). In the last Benin DHS report, anaemia prevalence in the same study area was 66·6 % in children under 5 years of age and 42·4 % in women of reproductive age[7]. In the present study, the prevalence of anaemia in women and children is much higher, suggesting no improvement from 2011 to 2015. Several factors might explain these findings. First, although the health authorities in Benin included different strategies to reduce child malnutrition and low birth weight, and also vitamin A, Fe and iodine deficiencies through supplementation, food diversification and fortification[13,32–34], there is a lack of information to evaluate the coverage and effectiveness of these interventions at the regional level. Second, about 21 % of households in the study area were reported food insecure since farming, which is the primary means of survival, is limited to the rainy season[5]. Diets are also based predominantly on starchy staples with little or no animal products and few fresh fruits and vegetables[1,2,7]. According to the 2012 Benin DHS, only 28·3 and 33·8 % of children received the minimum diet diversity and minimum acceptable diet, respectively[7], reflecting the higher rates of poverty and less diverse production portfolios in the study area. The prevalence of undernutrition among children in our sample was also greater than in the rest of the

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Table 4 Determinants of anaemia, iron and vitamin A status* among non-pregnant women of reproductive age; Kalalé district, northern Benin, January–March 2014

	Anaemia		ID		IDA		VAD	
	AOR	95 % CI	AOR	95 % CI	AOR	95 % CI	AOR	95 % CI
Mother/caregiver characteristics								
Mother's age								
30–39 years	1·12	0·73, 1·74	0·53	0·20, 1·38	**0·40**	**0·14, 0·96**	1·09	0·58, 2·05
40–49 years	1·42	0·65, 3·06	0·25	0·03, 1·97	0·66	0·10, 4·14	0·88	0·25, 3·12
15–29 years	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Mother's education								
No	n/s		0·46	0·09, 2·21	1·26	0·21, 7·50	**3·89**	**1·59, 19·07**
Yes	–	–	1·00	Ref.	1·00	Ref.	1·00	Ref.
Mother's occupation								
Agricultural/other labour	n/s		0·57	0·31, 2·06	0·61	0·15, 2·55	0·93	0·47, 1·87
Service/business	–	–	**0·20**	**0·03, 0·95**	**0·15**	**0·04, 0·93**	2·04	0·82, 5·07
Others	–	–	1·00	Ref.	1·00	Ref.	1·00	Ref.
Mother's food diversity score								
Low	1·16	0·70, 1·93	**2·13**	**1·68, 6·61**	1·22	0·39, 3·77	1·06	0·42, 2·64
Median	1·01	0·58, 1·74	1·86	0·55, 6·27	0·66	0·17, 2·51	1·66	0·73, 3·79
High	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Mother's BMI								
Underweight	0·79	0·39, 1·59	**5·48**	**1·35, 22·19**	2·69	0·65, 11·19	0·88	0·34, 2·29
Overweight	**0·46**	**0·24, 0·88**	1·53	0·48, 4·87	1·62	0·16, 5·28	**0·26**	**0·07, 0·92**
Obesity	0·30	0·08, 1·17	0·62	0·02, 16·67	0·71	0·21, 2·49	0·87	0·13, 5·82
Normal weight	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Mother's inflammation status								
Present	**2·02**	**1·23, 3·32**	2·25	3·19, 7·05	**5·7**	**1·22, 16·98**	n/s	
Absent	1·00	Ref.	1·00	Ref.	1·00	Ref.	–	–
Consumed protein foods								
≤4 pieces/week	1·16	0·75, 1·80	n/s		n/s		**2·54**	**1·29, 5·01**
>4 pieces/week	1·00	Ref.	–	–	–	–	1·00	Ref.
Mother's ID								
Present	–	–	–	–	–	–	**1·60**	**1·13, 4·30**
Absent	n/s		n/s		n/s		1·00	Ref.
Household characteristics								
Household ethnicity								
Boo	n/s		**3·01**	**1·85, 10·67**	3·08	0·89, 10·68	**0·25**	**0·11, 0·59**
Peulh	–	–	2·69	0·78, 9·29	2·69	0·85, 8·50	0·82	0·39, 1·72
Boko	–	–	0·82	0·16, 4·25	0·44	0·05, 3·91	**0·14**	**0·03, 0·67**
Bariba	–	–	0·68	0·14, 3·36	0·24	0·03, 1·95	**0·27**	**0·08, 0·89**
Gando	–	–	1·00	Ref.	1·00	Ref.	1·00	Ref.
Fruits and vegetables consumption								
Never	1·02	0·47, 2·24	1·27	0·35, 4·60	1·81	0·46, 7·10	**2·72**	**1·09, 9·65**
Several times per month	1·16	0·65, 2·06	**4·12**	**1·32, 3·86**	**3·43**	**1·92, 12·78**	1·81	0·77, 4·24
Once or twice per week	1·45	0·81, 2·55	1·20	1·03, 4·12	0·50	0·09, 2·86	1·52	0·63, 3·70
Almost every day	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Group membership								
NWG	0·99	0·64, 1·55	0·97	0·39, 2·37	0·42	0·16, 1·13	n/s	
WG	1·00	Ref.	1·00	Ref.	1·00	Ref.	–	–
Household size								
≥5 persons	1·15	0·68, 1·92	n/s		**4·02**	**1·91, 17·69**	n/s	
2–4 persons	1·00	Ref.	–	–	1·00	Ref.	–	–
Socio-economic status								
Poorest	**1·79**	**1·01, 3·20**	1·18	0·35, 4·06	1·30	0·34, 4·91	1·84	0·72, 4·73
Poor	1·25	0·69, 2·25	0·49	0·12, 1·95	0·93	0·21, 4·04	1·58	0·61, 4·07
Intermediate	1·15	0·64, 2·06	0·53	0·13, 2·21	0·74	0·15, 3·61	1·13	0·44, 2·91
Wealthiest	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Latrine								
No	n/s		**2·68**	**1·45, 7·26**	1·08	0·27, 4·34	n/s	
Yes	–	–	1·00	Ref.	1·00	Ref.	–	–
Radio news								
≥3 d/week	n/s		**2·12**	**1·24, 9·95**	1·27	0·51, 3·18	**1·40**	**1·18, 4·07**
>3 d/week	–	–	1·00	Ref.	1·00	Ref.	1·00	Ref.

ID, Fe deficiency; IDA, Fe-deficiency anaemia; VAD, vitamin A deficiency; AOR, adjusted OR; NWG, non-women's group; WG, women's group; ref., reference category; n/s, not retained in model.
*Twenty-five independent variables were initially entered into each logistic regression equation. Variables with a *P* value >0·2 were eliminated from the model (n/s). The reported AOR are adjusted for the independent variables remaining in the equation. Bold font indicates a statistically significant association.

country (stunting 40 *v.* 37 %, wasting 11 % *v.* 5 %, underweight 24 % *v.* 17, respectively), again reflecting higher poverty rates. However, it is important to note that our data were obtained from a non-randomized study population; therefore, results should be interpreted with caution.

The measure of Fe status, not often included in surveys in Benin, indicated high prevalence of ID among women and children (>15 %), which highlights the significance of this nutritional deficit in the studied area. In 2013, Rohner *et al.*[35] found lower prevalence of ID among both populations in rural areas of the Ivory Coast: women

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Table 5 Determinants of anaemia, iron and vitamin A status* among children aged 6–59 months; Kalalé district, northern Benin, January–March 2014

	Anaemia		ID		IDA		VAD	
	AOR	95 % CI	AOR	95 % CI	AOR	95 % CI	AOR	95 % CI
Child characteristics								
Child's age								
6–11 months	**2·42**	**1·07, 5·48**	1·37	0·70, 2·66	1·11	0·45, 2·70	0·29	0·08, 1·02
12–23 months	**1·93**	**1·06, 3·49**	**1·39**	**1·17, 5·21**	**1·67**	**1·05, 4·93**	0·69	0·26, 1·82
24–59 months	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Child's food diversity score								
Low	**2·51**	**1·08, 5·86**	1·38	0·27, 3·53	1·18	0·45, 3·05	**4·19**	**1·52, 11·56**
Median	0·95	0·42, 2·14	1·18	0·45, 3·14	0·92	0·34, 2·52	2·40	0·81, 7·10
High	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Child's inflammation								
Present	1·53	0·80, 2·93	**3·48**	**1·77, 6·82**	**1·85**	**1·26, 6·41**	**3·12**	**1·92, 10·63**
Absent	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Stunting								
Yes	n/s		**2·17**	**1·17, 4·02**	**2·16**	**1·05, 4·46**	1·77	0·79, 3·95
No	–	–	1·00	Ref.	1·00	Ref.	1·00	Ref.
Mother's characteristics								
Mother's age								
30–39 years	**1·47**	**1·23, 5·98**	1·36	0·70, 2·66	1·70	0·75, 3·83	0·75	0·32, 1·77
40–49 years	0·64	0·22, 1·86	0·61	0·17, 2·21	0·97	0·24, 3·95	1·57	0·40, 6·12
15–29 years	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Mother's occupation								
Agricultural/other labour	**2·42**	**1·12, 5·22**	**2·26**	**1·06, 4·78**	**4·60**	**1·67, 12·62**	1·46	0·58, 3·64
Service/business	2·50	0·87, 7·16	2·07	0·73, 5·83	2·82	0·32, 7·59	0·60	0·17, 2·11
Others	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Mother's BMI								
Underweight	2·04	0·32, 13·23	**4·06**	**1·31, 12·62**	**5·31**	**1·40, 20·14**	1·18	0·14, 9·80
Overweight	0·62	0·24, 1·57	1·22	0·48, 3·06	1·41	0·47, 4·24	0·68	0·16, 2·97
Obesity	1·76	0·43, 7·21	0·41	0·03, 5·23	1·09	0·06, 8·42	0·90	0·29, 2·80
Normal weight	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Mother's VAD								
Present	n/s		n/s		n/s		**3·42**	**1·24, 9·45**
Absent	–	–	–	–			1·00	Ref.
Mother's IDA								
Present	n/s		n/s		**2·85**	**1·08, 7·55**	n/s	
Absent	–	–	–	–	1·00	Ref.	–	–
Mother's anaemia								
Present	**2·42**	**1·26, 4·63**	n/s		n/s		n/s	
Absent	1·00	Ref.	–	–	–	–	–	–
Household characteristics								
Group membership								
NWG	1·18	0·61, 2·29	1·09	0·57, 2·07	0·80	0·37, 1·74	**2·88**	**1·03, 6·25**
WG	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Household size								
≥5 persons	1·21	0·57, 2·56	**2·79**	**1·08, 5·78**	n/s		1·64	0·68, 3·95
2–4 persons	1·00	Ref.	1·00	Ref.	–	–	1·00	Ref.
Unsafe water								
Yes	**2·18**	**1·09, 4·82**	n/s		n/s		2·72	0·75, 9·92
No	1·00	Ref.	–	–	–	–	1·00	Ref.
Socio-economic status								
Poorest	1·07	0·39, 2·92	**2·89**	**1·07, 5·70**	1·97	0·67, 5·78	0·55	0·16, 1·83
Poor	1·27	0·46, 3·51	1·15	0·42, 3·16	1·86	0·54, 6·46	0·51	0·14, 1·78
Intermediate	0·73	0·29, 1·84	0·93	0·35, 2·49	0·79	0·22, 2·87	0·44	0·13, 1·42
Wealthiest	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.
Radio news								
≤3 d/week	**2·15**	**1·06, 4·36**	**3·46**	**1·21, 9·90**	1·32	0·57, 3·05	1·22	0·49, 3·04
>3 d/week	1·00	Ref.	1·00	Ref.	1·00	Ref.	1·00	Ref.

ID, Fe deficiency; IDA, Fe-deficiency anaemia; VAD, vitamin A deficiency; AOR, adjusted OR; NWG, non-women's group; WG, women's group; ref., reference category; n/s, not retained in model.
*Thirty independent variables were initially entered into each logistic regression equation. Variables with a *P* value >0·2 were eliminated from the model (n/s). The reported AOR are adjusted for the independent variables remaining in the equation. Bold font indicates a statistically significant association.

13·5 *v.* 18·3 % and children 8·6 *v.* 23·6 %. Geographical, economic, seasonal and behavioural variations of factors across these different settings may account for the difference. Contrary to Kassebaum *et al.*[36], ID accounted for a small proportion of anaemia (women 23·7 %, children 25·8 %) in the present study. A similar pattern of anaemia and ID was also observed by Nguyen *et al.* in Vietnam[37], suggesting that causes for anaemia other than ID, such as other micronutrient deficiencies (vitamin A, folate or vitamin B_{12}), intestinal parasites, malaria or haemoglobinopathies, could all be important factors. Haemoglobinopathies can cause a shift to the left in the Hb distribution, leading to more people having anaemia, while chronic inflammation can lead to anaemia through reduced erythropoiesis[38–42]. Unfortunately, we do not have data to identify which of these factors caused the anaemia in

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the present survey. Finally, the fact that more than half of the ID was not associated with anaemia suggests that daily Fe intake of the study population was sufficient to allow normal physiological functions but not adequate to build Fe stores. About 39 % of children and 17 % of women had SF concentration <30 mg/l. This is particularly important for women of reproductive age, as Fe stores of 300–500 mg/kg before pregnancy are recommended[43].

VAD was also recognized as a public health problem among young children as more than 20 % were deficient, whereas it was mild in women (<20 %)[28]. The 2006 Benin DHS showed a national prevalence of VAD in children of 70 % and of 12 % for women in the study area[9]. Although significant progress has been reported in reducing the prevalence of VAD in children, the high prevalence of VAD among both populations suggests that efforts to prevent VAD have to be maintained and even strengthened, especially for the under 5-year-old children[44,45]. Eliminating VAD through biannual mass supplementation with vitamin A has been the focus of Beninese government efforts. About 65 % of children in our sample received vitamin A supplements in the last 6 months. Of concern in the present study is that about 40 % of the surveyed children were at risk of two coexisting micronutrient deficiencies. This result could explain why some interventions focused on single micronutrients such as Fe lack effectiveness in Benin. In India, for instance, vitamin A supplementation of deficient children resulted in a significant increase in Hb and serum Fe[46]. However, Stoltzfus found that vitamin A supplementation could not overcome ID in all settings[47]. Therefore, Beninese children need combinations of multi-micronutrient sources. Other complementary types of intervention, such as food fortification or food diversification, should also be planned and evaluated.

There is evidence that ID may result in low serum retinol due to impaired enzymatic activity for the synthesis of retinol-binding protein in the liver[48]. Our positive associations between maternal VAD and ID may also be due to poor diet quality, which is an important determinant of both nutrient deficiencies in our study population[49]. Additionally, we found that a lack of fruits and vegetables in the diet was significantly associated with ID and VAD whereas low consumption of protein foods was significantly associated with VAD, indicating that lack of access to those varieties of food items eventually deteriorates further the dietary quality of the study population[50]. Inflammation (e.g. due to intestinal parasites or malaria) was also a risk factor for anaemia, ID, IDA and VAD, while higher risks of anaemia and ID were found in households drinking untreated water and without a latrine. These findings suggest that more work is needed on examining the implementation of the current policy and the role of other interventions such as improvements in sanitation and hygiene that could potentially contribute to its prevention[51]. Finally, strong differences were found by ethnicity in the odds of ID and VAD. These findings serve as an important indicator of inequities in nutrition in Benin and indicate the need for further analysis of micronutrient deficiencies among and within ethnic groups.

On the other hand, most of the usual social determinants (age, family size, occupation, education and SES) showed significant associations with anaemia, ID, IDA and VAD. A similar non-nutritional factors-related trend in micronutrient deficiencies has been documented among women and children earlier[52–55]. For example, low SES was associated with increased odds of anaemia and ID while mothers' involvement in business/service was an important socio-economic factor for the non-occurrence of ID. This probably may be due to financial access to foods rich in Fe[50,56,57]. However, farming mothers in the present study had higher risk of anaemia and IDA compared with retired/student women, highlighting the need for appropriate behaviour change communication messages that could teach caregivers about the importance of dietary quality in a child's general health. Finally, the risk of anaemia was significantly greater in our study for the 6–11 months age group and the risks of ID and IDA in the 12–23 months age group. The last DHS of infant and young child feeding practices in Benin showed that complementary foods for young children have low energy density and low protein and micronutrient content because cereal flours and cereal porridges are the most commonly used foods, which might increase the risk of ID[7,58].

Although the present study provides useful data on prevalence of anaemia and vitamin A and Fe status in connection with dietary, socio-economic and demographic factors in vulnerable populations, it nevertheless has limitations. In Benin, seasonal undernutrition has been previously described as highly unpredictable, with considerable variations in the impact of seasonal stress within localities and even within households[5]. Serum micronutrient levels may also be affected by the time of day of blood sample collection, the fasting status of the study subjects and/or the seasonality of certain conditions such as the incidence of endemic infectious diseases. Therefore, consecutive and prospective measures are needed to better explore these associations over time. In consequence, periodical and longitudinal measurements may be desirable to test the role of seasonality in micronutrient deficiency prevalence. In addition, our results might not be generalizable to the rural Beninese population due to the non-randomization of women's groups, although no significant differences were found between WG and NWG. Another limitation of the present study is the lack of detailed information on vitamin A (timing of assessment) and Fe supplementation, which may provide useful information to explain the situation of micronutrient status in both populations studied. Finally, pre-analytical bias due to the complex field logistics and the samples' transport might have occurred. To reduce these potential

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biases, detailed guidelines on sample collection, preservation and transport were prepared and piloted prior to the fieldwork.

Conclusion

In summary, our findings highlight that anaemia and ID are public health problems among rural women and children in the Kalalé district of northern Benin. However, an important outcome from the study, and contrary to expectations, was that ID accounted for a small proportion of anaemia in the study area. Although the prevalence of VAD has decreased in children compared with previous surveys, VAD is still high in both populations. Furthermore, children from 12 to 59 months of age were particularly at risk of two coexisting micronutrient deficiencies, which could limit the effectiveness of programmes to optimize status for some micronutrients. Consequently, coordinated multi-micronutrient interventions for this age group are urgently needed to improve food diversity and the quality of complementary feeding. The findings also show the potential importance of programmes aimed simultaneously at improving economic, social and environmental conditions. Given the paucity of previous data in rural populations in Benin, our results represent a starting point for future research. These call for a coordinated study in various parts of the country to substantiate the current data so that appropriate and beneficial strategies for micronutrient supplementation can be planned.

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