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Prevalence and Associated Factors of Vitamin A Deficiency among Children and Women in Senegal

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Abstract

Background: Like many developing countries, Senegal does not have data on the extent of vitamin A deficiency (VAD) that is representative of its population. The present survey was conducted to fill this gap and to identify factors associated with VAD, prior to the introduction of a large-scale vitamin A oil fortification program.

Procedures: A nationwide representative cross-sectional survey involving 1887 children 12 to 59 months old and 1316 women of reproductive age (WRA) was conducted. Blood samples were collected and plasma concentrations of retinol (PR), C-reactive protein (CRP), and alpha-1-acid-glycoprotein were measured. PR was adjusted for subclinical inflammation using the BRINDA regression methodology. Multivariate logistic regression was used to identify factors associated with VAD.

Findings: The adjusted prevalence of VAD (PR ≤ 0.7 µmol/L) in children was 15.3% and differed by age group, area of residence, and socioeconomic status and half of them had subclinical inflammation. Among WRA, VAD was low (2.3%) and 18.1% had vitamin A insufficiency (VAI). Pregnant women were more affected by VAI (28.4%) and Dakar had lower figures compared with other cities and rural strata. Prevalence of VAI decreased with increasing wealth quintile. In logistic regression, abnormal CRP, poverty, scarce consumption of poultry, oysters, melon, red palm oil, palm kernel oil, *Saba senegalensis* fruit pulp (Maad) and cowpea, frequent consumption of leeks and consumption of *Leptadenia hastata* leaves (Mbuum tiakhat), were associated with VAD in children. For women, lower socioeconomic status, fair or poor health status and anemia were negatively associated with VAI.

Conclusions: In Senegal, VAD is a moderate public health problem in children and slight among women. Particular attention should be paid to children older than 23 months, pregnant women, rural populations, and poorest households. Nutritional interventions should be implemented alongside morbidity prevention and control.

Keywords: vitamin A deficiency, children 12-59 months, women of reproductive age, Senegal.

Introduction

Vitamin A is an essential nutrient involved in several biological processes including metabolism, hematopoiesis, embryogenesis, immune response, vision, reproduction, and growth [1]. Vitamin A deficiency (VAD) occurs mainly with low dietary intakes, impaired absorption of vitamin A or provitamin A carotenoids, and/or demand increased due to infections or life cycle. The consequences of VAD include the development of night blindness and ocular clinical signs, which can lead to full vision loss; anemia; and low resistance to infections, which increases the risk of morbidity and mortality [2-3].

Children under five years and Women of Reproductive Age (WRA) are the greatest vulnerable groups at risk for VAD according to the WHO [2]. Subclinical VAD affects more than 30% of under five year old children globally with the highest prevalence rate observed in sub-Saharan Africa (48%) [4]. Recent data suggested that VAD is the underlying cause of 2% of all deaths in this age group and the leading cause of preventable blindness. West African countries with published VAD figures indicated a public health problem in children with data varying from 7.3% to 63.1% in Liberia, Sierra Leone, Gambia, Ghana, Ivory Coast, Burkina-Faso, Nigeria, Benin, Guinea-Bissau and Mali [5-14]. WRA, especially pregnant women are also affected (19.1 million) and Africa represents over 20% of the global burden [2].

In 2009, Senegal, as in most developing countries, had limited data on the magnitude of VAD, which were either estimations or sub-national, outdated, and/or based on non-biochemical indicators. Using impression cytology, VAD was found in 11.4% of children aged 2-6 years in the rural area of the groundnut belt of Senegal [15]. Outlined biochemical results in children indicated a

VAD public health problem in the Department of Linguère (Louga region) and in Bambey, Kebemer, and Koungheul with prevalence of 71.5% and 26.1% in 1993 and 1997, respectively [16-17]. According to MI/UNICEF and the WHO, prevalence of VAD was estimated to be 61% (2004) and 37% (2005) [2, 18]. In women, statistics were disparate between geographical areas and over time, ranging from 57.1% to 2.5% between 1997 and 2006 while WHO estimated a national prevalence of 19.4% among pregnant women in 2009 [2, 18-20]. Night blindness was reported to affect 2% of women in Senegal [21]. Therefore, there was a real need for more accurate and representative data prior to the introduction of a large-scale vitamin A oil fortification program. To effectively address VAD at the population level, biological data on its extent were needed.

Several indicators of vitamin A status and their usefulness were already described [22-23]. Plasma retinol (PR), even if not reliable in diagnosing VAD in individuals due to its homeostatic control, is informative in assessing the severity of VAD among populations. However, retinol is altered during inflammation or infection by as much as 25%, leading to inaccurate estimations of deficiency in populations with high prevalence of infection [23-25]. As infection and inflammation are accompanied by an increase in the plasma concentration of acute phase proteins, their measure should be performed to adequately interpret PR concentration.

Thus, the aim of this survey was to assess, for the first time, the national prevalence of VAD and its determinants among children 12 to 59 months and WRA in Senegal.

Methods

Study Design and Population

A nationwide representative cross-sectional survey, involving children 12 to 59 months and WRA 15 to 49 years, was conducted during the dry season, from April to May 2010. According to food consumption and socioeconomic patterns, Senegal was stratified into 4 areas: Urban Dakar, Other urban cities, Rural 1 (rural areas of Tambacounda, Kedougou, Kolda, Sedhiou, and Ziguinchor regions) and Rural 2 (rural areas of Matam, Saint Louis, Louga, Thies, Diourbel, Fatick, Kaolack, Kaffrine, and Dakar). A two-stage stratified cluster sampling procedure with probability proportional to size was carried out to randomly select 1810 households from 57 clusters. The sample size calculation for women was based on prevalence of VAD during wet season (7%) reported by Gueye [20] in rural women of Sedhiou, southern Senegal. Considering a design effect of 2.9 and a precision of 5.0%, the minimal sample size required was 915 women. Using the above parameters and considering a prevalence of VAD of 61% [18], the sample size needed was 1104 for children aged 12 to 59 months. The survey protocol was approved by the ethical committee of the Senegalese Ministry of Health (CNERS). Women and children were eligible if informed written consent was provided by the heads of households, women, and children's mothers or caregivers.

Data Collection Procedures

Questionnaires were used to collect subjects' socioeconomic, socio-demographic, food consumption, and health history data.

Socioeconomic data included information on housing (occupancy status, drinking water source, type of toilet facilities, type of fuel used for cooking, type of household lighting) and ownership of durable goods (household equipment and livestock). These data were analyzed to generate a household's socioeconomic status indicator (wealth quintile) consisting of 5 categories (poorest, poor, intermediate, relatively wealthy, and wealthiest). Main sociodemographic data collected were physiological status (pregnant, breastfeeding, non-pregnant/non-breastfeeding) for women and gender and age for children. Children's food consumption habits (breastfeeding and complementary feeding practices) were reported as well as food frequency data and women's knowledge on vitamin A-rich foods. Health status and presence of clinical signs of VAD among children and women were carried out by physicians based on their medical history and physical examination. In addition, anemia status of children and women was investigated.

Blood Collection and Biological Measurement

Blood collection was performed by medical staff. Ten (10) and 5-7 milliliters of blood were drawn from women and children, respectively, by venipuncture using a single-use syringe, and metal-free vacuum collection tube containing lithium heparin as anticoagulant (Sarstedt). Hemoglobin (Hb) concentrations were measured on a drop of whole blood using an HemoCue® 201+ portable device (HemoCue AB) while the remaining sample was centrifuged at 3200 rpm for 12 minutes and plasma stored at -20°C in the field and kept at -80 °C in the laboratory until analysis. Plasma handling was done away from dust, under minimal light, and wrapped with aluminum foil to protect light-sensitive compounds from degradation. Samples were analyzed for plasma retinol (PR), C-reactive protein (CRP) and alpha-1 acid glycoprotein (AGP) in the Laboratoire de Recherche en Nutrition et Alimentation Humaine, Université Cheikh Anta Diop, Dakar, Senegal.

PR analysis was performed by high performance liquid chromatography using a methodology previously described [26] using a Spectra SYSTEM (Thermo Electron SAS) consisting of an SCM1000 vacuum membrane degasser, a pump P1000XR, an autosampler AS3000, a UV6000LP detector, and a SN 4000 module.

CRP and AGP concentrations were measured by immuno-turbidimetry using a Biosystems A15 automatic analyzer (Biosystems S.A.) with Biosystems kit reagents.

Cutoffs

PR concentration < 1.05 µmol/L was used to define vitamin A insufficiency (VAI) in women and PR ≤ 0.7 µmol/L was used to define VAD both in women and children [22-23]. Inflammation

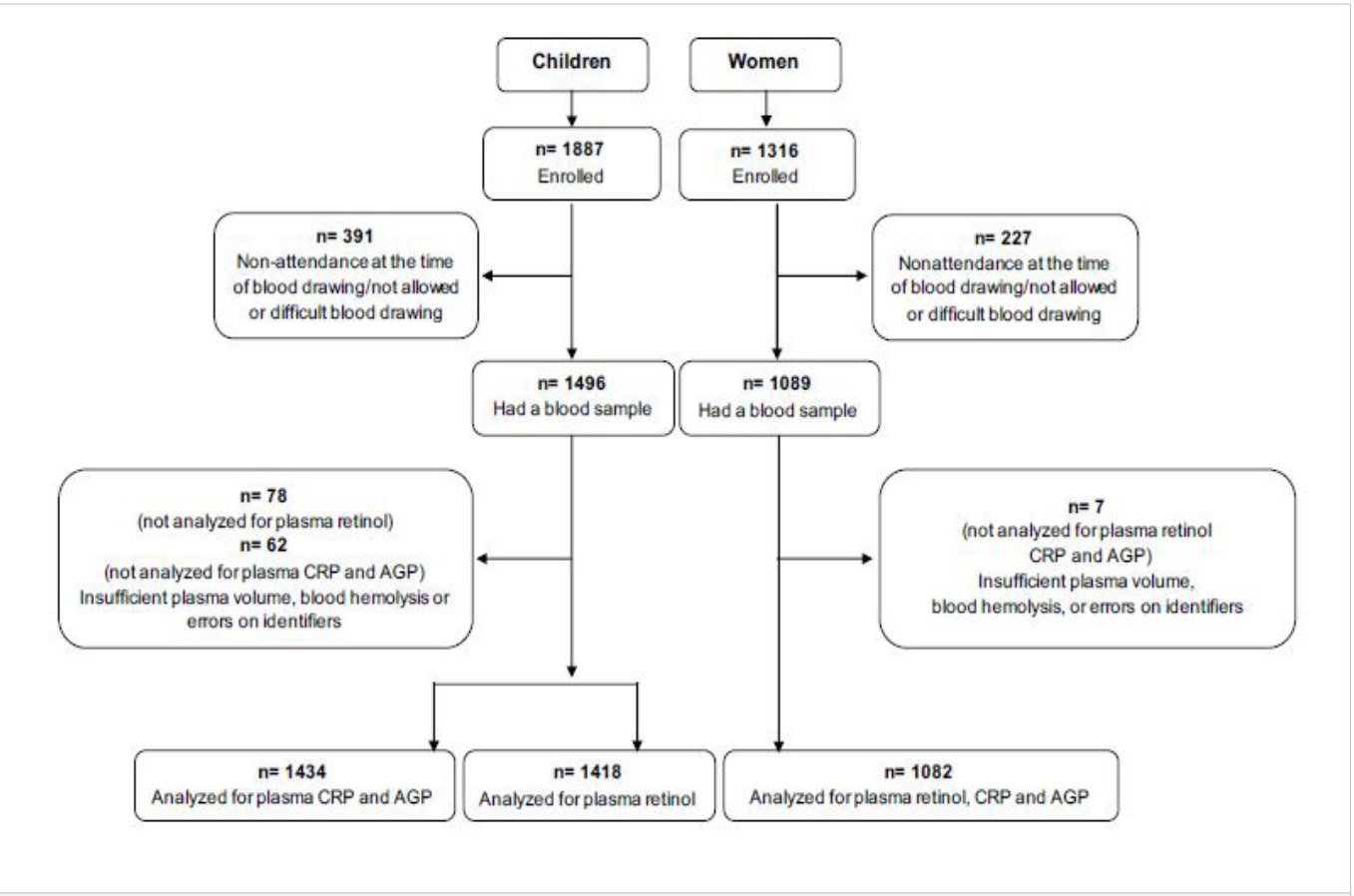

Figure 1: Flow chart of children 12 to 59 months and WRA recruited into a study to evaluate the national prevalence of VAD in Senegal, 2010

status was defined as CRP > 5 mg/L and/or AGP > 1 g/L [25]. Anemia was defined by Hb concentration < 110 g/L in children and pregnant women and Hb concentration < 120 g/L in non-pregnant women [27].

Adjustment of PR Concentration for Inflammation Using BRINDA Methodology

PR concentration was adjusted for subclinical inflammation using the regression correction approach developed by the BRINDA project as previously described [28-29] and prevalence of VAD was derived from those values. Briefly, adjusted PR values were obtained by subtracting the influence of CRP and AGP as follows: Retinoladjusted = retinolunadjusted – β1 (CRPobs - CRPref) – β2 (AGPobs - AGPref). In this equation, β1 and β2 are regression coefficients of CRP and AGP, respectively, obs is the individual observed value and ref is the reference value. Retinol, CRPobs, CRPref, AGPobs and AGPref are on natural logarithm scale. Internal reference values from our dataset (maximum value of the lowest CRP or AGP decile or 10^{th} percentile obtained) were used. Unlogged CRPref was 0.1 mg/L both for children and women while AGPref was 0.65 g/L and 0.55 g/L in children and women, respectively. Adjustments were only applied to individuals with either CRP concentrations> CRPref, AGP concentrations> AGPref or both. PR-adjusted values were back-transformed before applying cutoffs.

Statistical Analysis

Statistical analysis was performed using SPSS 15 (SPSS for Windows) and STATA/SE version 11.0 (STATA Corporation). Data were weighted for national representativeness of the results. Categorical variables were expressed as percentages, and continuous variables were expressed as means ± SD, except for CRP which was not normally distributed. Plasma concentrations of CRP were log-transformed and expressed as geometric means with 95% confidence interval [CI]. Student's t-test and analysis of variance (ANOVA) associated to a Bonferroni correction were used to compare means. Pearson's chi-squared was used to compare percentages. Comparisons were also done between age and sex groups in children, according to their physiological condition in women (pregnant, breastfeeding, non-pregnant/non-breastfeeding), and by area of residence for both children and women. Relation between PR and inflammation biomarkers was studied using Pearson's correlation coefficient (r). Multiple logistic regression model was used to assess association of socioeconomic, dietary, and health factors with VAD. For all statistical analyses, a significance level of 0.05 was used.

Results

Characteristics of the Study Population

In this study, 1316 WRA and 1887 children aged 12 to 59 months were targeted and PR concentration was measured on 1082 WRA and 1418 children [Figure 1]. Sociodemographic and health-related characteristics of the study population are presented in Table 1.

Table 1: Sociodemographic and health related characteristics of the study population

Characteristic	n	%
Children		
Age group, months		
12-23	462	24.2
24-35	485	25.8
36-47	480	26.2
48-59	442	23.8
Gender		
Girls	948	50.1
Illness (within last 15 days)		
Fever	395	65.7
Diarrhoea	119	25.1
Cough/ breathing trouble	198	40.1
VAS (within last 6 months)[1]	1079	78.5
Deworming (within last 6 months)	1068	77.7
Anemia	967	66.1
Women		
Age group, years		
15-19	286	20.5
20-24	283	22.5
25-29	199	16.2
30-34	187	13.7
35-39	145	10.7
40-44	121	10.2
45-49	92	6.1
Physiological status		
Pregnant	100	8.8
Lactating	270	25
NPNL[2]	713	66.2
Night blindness	18	3.9
Clinical signs of VAD	60	8
Anemia	498	47.5

[1]VAS: vitamin A supplementation

[2]NPNL: Non-Pregnant-Non-Lactating

Among the children, the mean age was 34.3 ± 13.0 months. Their proportion was almost equal between age groups while girls represented 50.1% of the children. Within the 15 days prior to the survey, fever, diarrhea, and cough/breathing trouble related to illness were reported in 65.7%, 25.1%, and 40.1% of children, respectively. Coverage of vitamin A supplementation in children within the last 6 months preceding the survey was 78.5% (n=1079) with disparities among strata (Dakar: 20.5%; Other cities: 84.4%; Rural 1: 51%; Rural 2: 95.2%). Among these, 77.7% were dewormed in the same period. The breastfeeding rate among children under 2 years was 98.1% (n=156). No case of night blindness was observed among the children. Mean age of WRA was 28 ± 9 years. Women aged 20-24 (22.5%) and 15-19 years (20.5%) were the most represented. The sample included 8.8% pregnant, 25% lactating, and 66.2% non-pregnant/non-lactating women (NPNL). Night blindness affected 3.9% (n=18) of women in their last pregnancy that resulted in a live birth during the past 3 years. Clinical signs of VAD were reported in 8% (n=60) of women. Anemia affected 66.1% (n=967) of children and 47.5% (n=498) of women.

Subclinical Inflammation among the Study Population

Inflammation was widespread and involved 1 out of 2 children, regardless of gender. Prevalence of inflammation decreased with age and the children aged 12-23 months and 24-35 months were the most affected groups [Table 2]. Among the women, over one quarter were affected by inflammation with significant differences according to their physiological status and the area of residence. The prevalence of inflammation in women was higher in Dakar compared to other cities and Rural 1 ($P < 0.01$).

Plasma Retinol Concentration and Prevalence of vitamin A Deficiency Among Children

PR concentration was normally distributed among children and its mean value was 0.90 ± 0.26 µmol/L [min: 0.16; max: 1.85] [Table 3]. According to gender, mean PR was higher in girls compared with boys ($P < 0.01$). PR concentration was significantly higher in children aged 12-23 months compared with those in 24-35 ($P < 0.01$), 36-47 ($P < 0.001$), and 48-59 ($P < 0.05$) months groups. According to their area of residence, no significant difference was observed in PR concentration between urban strata. The same scheme was observed between rural strata. However, mean PR concentration of children in urban strata were higher than in rural strata ($P < 0.001$). In addition, PR concentration increased meaningfully with socioeconomic status ($P < 0.05$).

According to inflammation status, both CRP and AGP were negatively and significantly associated with PR of children (CRP: r=-0.1162, $P < 0.001$; AGP: r=-0.1790, $P < 0.001$). Inflammation adjustment was done on PR using the BRINDA regression methodology. After adjustment with inflammation, mean PR concentration of children significantly increased (0.9 ± 0.26 vs. 0.99 ± 0.28 µmol/L, $P < 0.001$) and the difference observed between groups (gender, age, area of residence, and socioeconomic status) persisted. The prevalence of VAD after inflammation-adjustment in 12-59 months aged children was 15.3% [Table 3] with 0.1% severe cases [Table 5]. Prevalence of VAD was comparable between gender groups but significantly higher in 24-35 and 36-47-months aged children compared to

Table 2: Extent of subclinical inflammation among children and women[1]

			Stage of inflammation[2]		
	n	**Any inflammation[3]**	**Incubation**	**Early convalescence**	**Late convalescence**
Children					
National	1434	50.1	6.2	12.7	31.2
Gender					
Male	712	52.5	7	11.3	34.1
Female	722	47.7	5.3	14.1	28.3
Age group, months					
12-23	330	65.5[a]	6.7	20.6	38.2
24-35	359	54.8[b]	6.2	10.7	37.8
36-47	376	46.0[c]	7.9	12.8	25.3
48-59	132	36.5[d]	3.9	7.8	24.7
Area of residence					
Dakar	190	58.7[a]	16.6	14.9	27.3
Other cities	310	42.0[b]	5.4	12.7	24
Rural 1	382	43.0[c]	1.8	8.2	33
Rural 2	552	52.7[a, b, d]	5	13.2	34.4
Women					
National	1082	27.7	10.8	6.6	10.3
Physiological status					
Pregnant	99	26.9[a]	20.6	2.1	4.2
Lactating	267	34.4[a, b]	9	9.5	15.9
NPNL[4]	707	25.8[b, c]	10.4	6.2	9.1
Area of residence					
Dakar	293	33.3[a]	14.5	7	11.8
Other cities	182	29.8[a, b]	7.7	9	13.2
Rural 1	217	16.3[c]	3.4	8	4.9
Rural 2	390	22.8[b, d]	9.1	4.9	8.7

[1]Values are %. For each indicator, values between category of groups (in columns) with different superscript letters (a, b, c and d) are significantly different, P < 0.05

[2]Stage of inflammation: incubation (CRP> 5 mg/L and AGP≤ 1 g/L); early convalescence (CRP> 5 mg/L and AGP> 1 g/L); late convalescence (AGP >1 g/L and CRP≤ 5 mg/L)

[3]Any inflammation: CRP> 5 mg/L and/ or AGP> 1 g/L

[4]NPNL: Non-Pregnant-Non-Lactating

those aged 12-23 months. According to areas of residence, Rural 1 and Rural 2 had comparable figures but both presented higher prevalence of VAD than urban strata (*P < 0.001*). Children in the poorest households had a higher prevalence of VAD than in other household wealth categories.

Plasma Retinol Concentration and Prevalence of Vitamin A Deficiency among Women

Overall, mean PR concentration of WRA was 1.43 ± 0.44 µmol/L [min: 0.355; max: 3.851] [Table 4]. In WRA, weak but significant and negative correlation was observed between PR and CRP (r=-0.069, P=0.042) while no relationship was observed with AGP (r=0.033, P=0.274). Because of this weak relationship between inflammation and retinol in women, PR was not adjusted and the prevalence of VAD was estimated from non-adjusted values. Vitamin A insufficiency (VAI) was present in 18.1% of women among which 2.3% had VAD and 15.7% marginal vitamin A status [Table 5]. Mean PR was associated with physiological status and was lower in pregnant women compared with lactating (*P = 0.002*) and NPNL women (*P < 0.001*). Thus, the prevalence of VAI was higher in pregnant women (28.4%), comparable to lactating women but significantly different from NPNL women (*P < 0.001*). Furthermore, when women were separated into 2 groups (Pregnant vs Non-pregnant), VAI was higher in pregnant women (28.4% vs.17.2%, *P < 0.01*). According to the area of residence, PR concentration was significantly higher in urban Dakar (*P < 0.001*). Consequently, prevalence of VAI was significantly different among strata, lower in Dakar compared with others cities (*P < 0.01*) and rural strata (*P < 0.001*). Significant differences were also observed using socioeconomic status and consequently prevalence of VAI decreased with increasing wealth quintile from 37% in the poorest to 9.1% in the wealthiest (*P < 0.001*).

Factors associated with vitamin A deficiency among children

Logistic regression analysis [Table 6] showed that poverty status was associated with children's risk of VAD. Indeed, children from poorest, poor, and intermediate socioeconomic status households had 5.64, 2.33 and 4 times greater risk of VAD, respectively (*P < 0.01*) than their wealthiest peers. Incubation phase of inflammation was also a risk factor for low PR in this population group. Regression from dietary patterns showed that

Table 3: Plasma retinol concentrations and VAD prevalence according to gender, age group, area of residence and socioeconomic status among children[1]

		Plasma retinol (µmol/L)		VAD (%)	
	n	**Unadjusted**	**Adjusted[2]**	**Unadjusted**	**Adjusted[2]**
National	1418	0.9±0.26	0.99±0.28	24.5	15.3
Gender					
Girls	702	0.88±0.24[a]	0.97±0.26[a]	26.4	16.3
Boys	716	0.92±0.27[b]	1.0±0.3[b]	22.6	14.3
Age group, months					
12-23	324	0.96±0.28[c]	1.1±0.3[c]	19.4[c]	9.9[c]
24-35	353	0.89±0.26[d]	0.98±0.29[d]	26.6[d]	17.3[d]
36-47	374	0.87±0.25[d]	0.94±0.27[d]	30.2[e]	17.9[d]
48-59	366	0.90±0.23[d]	0.97±0.25[d]	20.9[c, d]	13.1[c, d]
Area of residence					
Dakar	190	0.97±0.24[a]	1.1±0.25[a]	15.0[a]	6.9[a]
Other cities	308	0.98±0.26[a]	1.1±0.28[a]	14.6[a]	8.2[a]
Rural 1	377	0.87±.25[b]	0.95±0.27[b]	27.0[b]	20.0[b]
Rural 2	543	0.86±0.25[b]	0.95±0.28[b]	29.8[b]	18.4[b]
Socioeconomic status					
Poorest	298	0.82±0.23[a]	0.89±0.25[a]	33.6[a]	25.3[a]
Poor	346	0.87±0.25[b]	0.95±0.27[b]	26.5[b]	15.6[b]
Intermediate	313	0.89±0.27[b]	0.98±0.3[b]	29.1[b]	20.7[b]
Wealthy	263	0.96±0.24[c]	1.05±0.26[c]	14.7[c]	5.7[c]
Wealthiest	193	1.0±0.26[c]	1.10±0.28[c]	14.3[c]	5.5[c]

[1]Values are mean±SD or %. For each indicator, values between category of groups (in columns) with different superscript letters (a, b, c and d) are significantly different, P < 0.05 (t-test or ANOVA for comparisons of means; Pearson chi[2] test for comparison of prevalence)

[2]Adjusted using the BRINDA methodology [28-29]

Table 4: Plasma retinol concentrations and prevalence of VAI according to physiological status, area of residence and socioeconomic status among women[1]

	n	**Plasma retinol, µmol/L**	**VAI (%)**
National	1082	1.43±0.44	18.1
Physiological status			
Pregnant	99	1.26±0.38[a]	28.4[a]
Lactating	267	1.42±0.47[b]	22.3[a, b]
NPNL[2]	707	1.46±0.43[b]	15.2[b, c]
Area of residence			
Dakar	293	1.57±0.42[a]	7.7[a]
Other cities	182	1.4±0.37[b]	16.8[b]
Rural 1	217	1.27±0.42[b, c]	31.8[c]
Rural 2	390	1.3±0.42[c]	28.3[c]
Socioeconomic status			
Poorest	193	1.2±0.4[a]	37.0[a]
Poor	174	1.3±0.4[a]	29.8[a, b]
Intermediate	228	1.41±0.47[a, b]	20.9[b, c]
Wealthy	219	1.46±0.39[b, c]	14.2[d]
Wealthiest	264	1.54±0.41[c]	6.9[e]

[1]Values are mean±SD or %. For each indicator, values between category of groups (in columns) with different superscript letters (a, b, c and d) are significantly different, P < 0.05

[2]NPNL: Non-Pregnant-Non-Lactating

rare or no consumption of foods rich in preformed vitamin A, vitamin A precursors and or dietary fats was predictive of VAD (poultry, oysters, melon, red palm oil, palm kernel oil). On the other hand, their frequent consumption or simple consumption were found to have significant protective effects (*P < 0.05*) on children' s VAD (*Saba senegalensis* fruit pulp, leeks) at the exception of *Leptadenia hastata* leaves (OR=1.91). Only rare consumption of cowpea was found to be protective for VAD (OR=0.47).

Factors Associated with Vitamin A Insufficiency among Women

Among women, the odds of VAI increased with lower socioeconomic status. Hence, compared with women from

the wealthiest households, those from relatively wealthy, intermediate, poor and poorest households had 2.53, 5.32, 5.95, and 8.44 greater risk of VAI, respectively [Table 6.] In addition, fair (OR=2.51) and poor (OR=7.96) health status as well as anemia status (OR=1.88) were negatively associated with VAI in women.

Table 5: Levels of vitamin A deficiency (VAD) among Senegalese children and women

	Prevalence of vitamin A deficiency	
	n	%
Children[1]	1418	
Normal status	1210	84.7
Marginal VAD	207	15.2
Severe VAD	1	0.1
Women[2]	1082	
Normal status	861	81.9
Marginal status	192	15.7
VAD	29	2.3

[1]Normal status: PR>0.7 µmol/L, Marginal VAD: 0.35<PR≤0.7 µmol/L), Severe VAD: PR ≤0.35 µmol/L

[2]Normal status: PR≥1.05 µmol/L, Marginal VA status: 0.7<PR<1.05 µmol/L, VAD: PR≤ 0.7 µmol/L

Discussion

Nationally, data from the present study revealed that VAD was a moderate public health problem in children aged 12 to 59 months according to the WHO classification criteria using PR as the indicator [23]. Our findings were lower than the estimations of 37% and 61% reported by the WHO and MI/UNICEF, respectively, probably due to the methodology based on regression model estimates using member countries reported studies [2, 18]. The prevalence of VAD observed in our study seems to be lower than those of all West African countries with published national statistics with the exception of Liberia (7.3%), i.e., Sierra Leone (17.4%), Gambia (18.3%), Ghana (20.8%), Ivory Coast (24.1%), and Nigeria (29.5%) [5-9, 11]. However, comparison should be done with caution because those data were mainly based on RBP measurement instead of PR concentration as recommended by the WHO for population surveys and used different methods of correction for inflammation, when applicable. Nevertheless, as observed in bivariate analysis, VAD was mild among children 12-23 months and those from urban strata but severe among children living in the poorest wealth quintile households. These dissimilarities might be linked to the higher rate of breastfeeding (98.1%) in 12-23 months of this study associated with adequate vitamin A status in lactating women and differences in socioeconomic status between urban and rural areas. When comparing unadjusted VAD with subnational figures reported in 1997 (26.1%), it seems that prevalence of VAD has not substantially decreased over the past decade despite the implementation of vitamin A supplementation (VAS), the only large-scale strategy implemented at the time of the survey which started since 1999 among children under 5 years. VAS coverage has declined between 2005 (75%) [21] to present (63%) [30] and its rate stayed below the target of the Senegalese VAS program (95%) [31]. This situation highlights the need to strengthen the national VAS program and consolidates the VA cooking oil fortification program as a control strategy for VAD with focus on children older than 23 months, children from rural areas, and those living in the poorest households. In less affected population groups, VAD control programs should consider that vitamin A might be provided in excess due to overlapping programs and might cause hypervitaminosis A in the long-term [32], meaning that inclusive population monitoring is needed with biomarkers more sensitive than PR concentrations [33-34].

In multivariate analysis, poverty, abnormal CRP, and scarce or no consumption of several vitamin A food sources were found to be predictive of VAD risk in Senegalese children. Indeed, poor socioeconomic status could have a negative impact on food security by limiting access to sufficient and nutritious food, thus compromising the satisfaction of nutritional requirements of the population [35-36]. It could also affect financial access to adequate care. Moreover, morbidity prevention and control should be consolidated, regarding the high occurrence of illness observed in children that was corroborated by high prevalence of inflammation and the association between VAD and abnormal CRP concentration. Alongside these efforts, nutrition education promoting adequate dietary intake of preformed and / or vitamin A precursors rich foods such as poultry, oysters, melon, leeks, red palm oil and *Saba senegalensis* fruit pulp should be considered. The risk of VAD associated with consumption of *Leptadenia hastata* leaves reported to be rich in β-carotene [37] might be related to the low bioavailability associated with the matrix in which the provitamin carotenoids are incorporated, antinutritional factors, or poverty. In this study, cowpea's rare consumption was found to have a protective effect on VAD. Given the higher protein content of cowpea (20% to 40%), its frequent consumption might reduce the activity of the enzyme carotene dioxygenase which is involved in β-carotene absorption [38], explaining a protective effect in those consuming cowpeas rarely. The protective effect of palm kernel oil on the risk of VAD can be explained by the known improvement effect of dietary fats on vitamin A and provitamin A carotenoid absorption. In addition, even if lacking vitamin A precursors, palm kernel oil could be contaminated from palm fruit pulp during traditional transformation processes. Otherwise, this association needs further investigation.

Among Senegalese women, prevalence of VAD was low (2.3%), depicting a minor public health problem, while 15.7% of them was at risk of VAD. The prevalence of VAD is consistent with the 2.5% found during dry season in the rural area of Sedhiou in 2006 [20]. It is also comparable to Sierra Leone (2.1%) but slightly over the data from Ghana (1.5%) and Gambia (1.8%) [6-8]. Pregnant women were most affected by VAI, probably due to either hemodilution or the 60% additional vitamin A requirements needed to ensure normal fetal growth, to provide a limited reserve in the fetal liver, and to maintain their own tissue growth [39]. Biochemical results were in line with the reported extent of night blindness among women (3.9%), greater than the

Table 6: Factors associated with VAD among children and women in Senegal

	Odds ratio	95% CI[1]	P value
Children			
Socioeconomic status			
Wealthiest	1	Ref.	
Intermediate	4	2.10-7.64	0.000
Poor	2.33	1.19-4.57	0.013
Poorest	5.64	2.97-10.7	0.000
Inflammation/Infection[2]			
No	1	Ref.	
Yes	2.04	1.26-3.3	0.004
Food consumption frequency[3]			
Poultry			
Frequent	1	Ref.	
Rare	1.78	1.14-2.78	0.011
No	2.05	1.08-3.89	0.027
Oysters			
Frequent	1	Ref.	
Rare	3.03	1.21-7.53	0.017
Melon			
Frequent	1	Ref.	
Rare	2.3	1.35-3.92	0.002
Saba senegalensis fruit pulp (Maad)			
No	1	Ref.	
Rare	0.5	0.29-0.85	0.011
Leeks			
No	1	Ref.	
Frequent	0.1	0.014-0.83	0.033
Leptadenia hastata leaves (Mbuum tiakhat)			
No	1	Ref.	
Yes	1.91	1.25-2.92	0.003
Cowpea			
Frequent	1	Ref.	
Rare	0.47	0.27-0.79	0.005
Red palm oil			
Frequent	1	Ref.	
No	1.9	1.21-2.98	0.005
Palm kernel oil			
Frequent	1	Ref.	
No	2.7	1.25-5.83	0.011
Women			
Socioeconomic status			
Wealthiest	1	Ref.	
Relatively wealthy	2.53	1.26-5.04	0.008
Intermediate	5.32	2.80-10.08	0.000
Poor	5.95	3.08-11.49	0.000
Poorest	8.44	4.46-15.98	0.000
General health status			
Excellent	1	Ref.	
Fair	2.51	1.5-4.19	0.000
Poor	7.96	2.2-28.82	0.002
Anemia			
No	1	Ref.	
Yes	1.88	1.33-2.65	0.000

[1]CI = confidence interval

[2]Incubation (CRP> 5 mg/L and AGP≤ 1 g/L)

[3]Food consumption frequency: Frequent (at least 1 time a day or 1 to 3 times per week); Rare (1 time a month or less); No (never consumed at the period of the survey)

prevalence of 2% found among Senegalese women in 2005 [21] but below the cutoff point of 5% defining a public health problem [40].

As for children, poverty was a predictive factor of VAI, the lower the socio-economic status, the higher the risk of VAI. An increased risk of insufficient vitamin A intakes associated with lower socioeconomic status was reported in WRA in Vietnam [41]. Anemia was found to be associated with VAI in Senegalese women. This result supports the well-known relationship between VAD and anemia that has been documented [42-43]. Analogous findings were observed among WRA in Cameroon and Ivory Coast as well as pregnant women in Nepal, India, Iran, Bangladesh, China, and Brazil [44-50]. Even if potential mechanisms by which vitamin A influences anemia have been proposed [43], the pathogenesis of this association remains unclear. However, VAD is known to impair mobilization of iron stores, decreasing iron supplies to the bone marrow and reducing hemoglobin synthesis [51]. Concerning the increased risk of VAI with fair or poor health status, it was likely due to the synergistic relationship between altered vitamin A status and occurrence of infections. This calls to enhanced management of acute inflammation and / or infection particularly, as suggested by the correlation, even weak, between PR and CRP.

Conclusion

In conclusion, this survey, the first nationally-representative in Senegal, showed that vitamin A deficiency is a moderate public health problem in children and marginal among women. But particular attention must be paid to children over 23 months, pregnant women, rural populations, and the poorest households who are the most vulnerable. Based on reported predictors of VAD among our study population, improvement of VAD in Senegal requires a multiple approach strategy: 1) strengthening the VAS program in order to prevent inflammation and infection related illnesses among children; 2) preventing and controlling anemia among women; 3) implementing the vitamin A fortification program in order to reach high geographical coverage and to make accessible adequately fortified oil, especially for the most vulnerable. This also implies proper monitoring and evaluation to reduce risk of vitamin A excess among groups less affected by VAD; and 4) reinforcing nutrition education by promoting local vitamin A rich products.

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Author Contributions

MHF participated in data management, performed statistical analysis and drafted the manuscript. SW, ATG, and NID participated in the conceptualization of the study. NID supervised vitamin A assays. AD and AAD participated in data collection and data management. AB and PMDDS participated in data analysis. All the authors reviewed the manuscript and approved its final submitted version.

Declarations

Conflict of Interest

The author(s) declared no conflicts of interest with any financial/research/academic organization with regards to the research, authorship, and/or publication of this article.

Ethical Approval

The protocol was approved by the ethical committee of the Senegalese Ministry of Health (CNERS) under the reference number SEN 38/08 ITA-COSFAM. Fully informed written consent has been obtained from survey participants.

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