

# The prevalence of Vitamin A deficiency in 1994 on an atoll of the Marshall Islands and its relationship to locally grown food

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## Abstract

In an area of the world not previously studied for the presence of nutritional deficiencies, this study conducted in 1994, examined the prevalence of Vitamin A deficiency on a representative atoll of the Marshall Islands. All children ages three through ten living on Mili atoll were surveyed. The study was conducted house-to-house with all 38 subjects on the atoll voluntarily enrolling in the study.

Vitamin A status was assessed by conjunctival impression cytology with transfer (ICT), clinical ophthalmic signs, and nutritional survey in all children ages three through ten living on Mili atoll, Republic of the Marshall Islands. Forty-seven percent had xerophthannia (5% with XN, 39% with XN + XIA, and 3% with XN + XIB). More than three-quarters (78%) were ICT abnormal, indicating 31% of the population had mild sub-clinical vitamin A deficiency. Eighty-six percent of the children had not received the U.S. recommended daily allowance of vitamin A in the previous week. Given the World Health Organization's published guidelines that anything greater than a 1% prevalence, Vitamin A deficiency on Mili atoll may be classified as a significant public health problem.

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## Introduction

The Republic of the Marshall Islands, a developing country, is located approximately 2,300 miles southwest of Hawaii. Comprised of 34 low coral atolls and with a population of 45,000 people, it is one of several countries located in the region named Micronesia. Within this region, some island countries are volcanic with a better nutrient mix in the soils and some are coral atolls with poor soil structure.

Vitamin A deficiency is a major health problem, affecting 200 million children around the world and leading to blindness in 500,000 of them every year.<sup>1</sup> In the only published study of vitamin A deficiency in a country in the Micronesia region, 57% of the three through seven year olds sampled in Chuuk, Federated States of Micronesia had abnormal conjunctival impression cytology reflecting subclinical vitamin A deficiency.<sup>2</sup> Chuuk lagoon islands are of volcanic origin, with soil much richer in nutrients for a greater variety of locally grown foods high in vitamin A content than is available on the coral atolls of the Marshall Islands.

Vitamin A is an essential nutrient for vision, epithelial cell differentiation, growth, and immunocompetence. The major sources of vitamin A are plant carotenoid pigments, such as beta-carotene found primarily in green leaf and yellow vegetables, and -retinyl esters in meat. These alternative forms of vitamin A are less efficiently converted to retinol in the intestine. Four to six times as much ingested beta-carotene as vitamin A is required for the same effect. The recommended daily dose of Vitamin A ranges from 800 to 1200 ug of retinol or its equivalent.<sup>3</sup>

After being absorbed by the intestinal lining, about half of the ingested Vitamin A is retained and stored in the liver. When more vitamin A is needed, it is released into the blood complexed with retinol binding protein (RBP), a specific carrier protein produced by the liver; this complex is called holo RBP. Holo RBP is then transported to the cells where it is utilized in differentiation, vision and growth.

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The initial sign of vitamin A deficiency is dryness of the conjunctiva (xerosis conjunctivae). It is paralleled by night blindness and if the deficiency continues, Bitot spots may occur. Bitot spots occur on the exposed bulbar conjunctiva, most typically in the palpebral fissure on the temporal side. It appears as a highly refractile mass with a silvery gray hue and a foamy surface.

If vitamin A status deteriorates further in a patient with xerosis conjunctivae, the disease progresses to keratomalacia. Keratomalacia, or softening of the cornea, may be generalized or localized and may lead to destruction of the eye. Blindness is caused by loss of retinal in the photopigments of the retina.

Xerophthalmia has been classified into the following categories:<sup>3</sup>

XN	<i>Night blindness</i>
XIA	<i>Conjunctival xerosis</i>
XIB	<i>Bitot spots</i>
X2	<i>Corneal xerosis</i>
X3A	<i>Corneal ulceration keratomalacia involving less than one third of the corneal surface</i>
X3B	<i>Corneal ulceration/keratomalacia involving one-third or more of the corneal surface</i>
XF	<i>Xerophthalmic fundus</i>
XS	<i>Corneal scars presumed secondary to xerophthalmia</i>

The hypotheses for this study were the following:

1. The prevalence of night blindness on Mili atoll is hypothesized to be greater than the 1% defined by the World Health Organization as being indicative of a significant public health problem.<sup>3</sup>
2. Age would make a difference in who experienced vitamin A deficiency, with decreased prevalence in older children due to their ability to obtain food for themselves.
3. Intake of vitamin A will be inversely related to night blindness and xerophthalmia.

## Subjects and methods

**Setting:** The study was performed on Mili atoll, one of the 34 atolls in the Marshall Islands, which has a population of 150 including 38 children aged three through ten. The atoll selected for survey was determined by the Public Health Division of the Ministry of Health based on its accessibility, population, and representation of nutritional resources on other atolls. The atolls of Majuro and Kwajalein were not considered because of their relatively urban population and access to health care. Because of the USDA supplemental food provided to

the people of the irradiated atolls of Rongelap, Bikini, and Enewetok, the atolls of Ujelong, Enewetok, Rongelap, Rongerik, and Bikini were not surveyed. The atoll of Wotje was supplemented with soil brought from Japan during World War II, so its inhabitants benefit from foodstuffs grown in enriched soil and was not surveyed since it is not representative of the nutrient-poor soil found on other outer islands. All the other 33 atolls have similar soil and vegetation composition and only six food items (fish, breadfruit, papaya, bananas, pandanus, and coconuts) are available naturally. No other food grows because of the combination of salt spray bums to leaves, lack of fresh water, and poor soil. There are no leafy green vegetables grown and the only obvious source of vitamin A is papaya. The survey was conducted in June 1994, because it was three months after the end of the typical dry period and locally grown food are easily available.

**Subjects:** All 38 children on Mili atoll between the ages of three through ten participated in this study. A house-to-house survey of all inhabitants of Mili atoll was conducted with children ages three through ten being interviewed, examined, and tested. Informed consent was obtained from the parent and/or patient in each case. Data for this study was obtained from a standardized verbal nutritional questionnaire developed by the author, a history of night blindness, a general physical exam with emphasis on ophthalmic findings, and laboratory results from the conjunctival impression cytology with transfer (ICT) test.

**Methods:** There are numerous methods, such as ophthalmic exam, nutrition questionnaire, conjunctival impression cytology, rose bengal eye staining, serum retinol levels, high pressure liquid chromatography (HPLC), relative dose response test, immunoassay for circulating retinol binding protein (RBP), and liver biopsy, of assessing

vitamin A status, none of which is without limitations. A survey in 1989 had been attempted in the Marshall Islands with serum retinol levels and clinical exam, but failed because of inadequate refrigeration, storage conditions, and extended transit times to Honolulu where the nearest high performance liquid chromatography machine was located. The Marshallese experience exemplifies the need for a simple, but sensitive and specific screening test.

Methods not used in this study, and their limitations, are extensively detailed in the literature.<sup>1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13</sup>

**Ophthalmologic investigation:** Currently, the ocular changes of xerophthalmia are the most accessible physiologic indicator and are used in most community surveys. All ocular examinations were carried out by the

author, who was trained to recognize conjunctival xerosis, Bitot spots, corneal xerosis, and keratomalacia by Dr. Gene Gabriel, a US board-certified ophthalmologist. The standard diagnostic criteria, except Bitot sports, of clinical signs of xerophthalmia were used.<sup>14</sup> Bitot spots were not a criteria for determining vitamin A deficiency because they may not always indicate vitamin A deficiency and chronic Bitot spots may become adherent and persist even after vitamin A therapy.<sup>15</sup>

**Night blindness and nutrition questionnaire:** Information on night blindness was elicited from parents and caretakers using the local word for the condition, *bilti ibon*. The nutrition survey determined the average amount and frequency per week for ingestion of the six kinds of naturally available food. Those are: fresh fish, pandanus (*Panus odoratissimus*), breadfruit (*Artocarpus altilis*), papaya, bananas, and coconuts. Additionally, the survey asked about the intake of white rice and "tinned meats" (corned beef, mackerel, and Spam). Papaya contains 2.01 retinol equivalents (RE) per gram, slightly more than one pound of papaya per day satisfies the US RDA of 1,000 RE. The vitamin A content of bananas is negligible at 0.3 RE per gram; the vitamin A content of pandanus, breadfruit, and coconuts has yet to be established, but is thought to be low. Fish liver, high in vitamin A, is not eaten in the Marshall Islands. Three ounces of mackerel contains between 10-24% of the US RDA.

**Impression Cytology with Transfer (ICT):** The method described by Escoute for the ICT, a modification of the ICT method used by Carlier, was used. The method is as follows. The test is conducted on both eyes for each patient. Cellulose acetate filter paper (Millipore HAWP 304) is cut into 2.5 mm x 25 mm strips. The distal end of the strip is applied to the temporal quadrant of the conjunctiva for five seconds. The cells collected on the paper are immediately transferred to a glass slide by simple application and light finger pressure. These cells are fixed in 95% alcohol for 15 min-

**Table 1**

Age (years)	N	%
3	2	5.3
4	7	18.4
5	4	10.5
6	5	13.2
7	5	13.2
8	3	7.9
9	5	13.2
10	7	18.4
<b>Total</b>	<b>38</b>	<b>100.0</b>
<i>Sample: 18 (47%) males. 20 (53%) females.</i>		
<i>Total: 38</i>		

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A normal impression cytology is characterized by small epithelial cells without distinct borders and the presence of goblet cells or mucin spots with nuclei. In a vitamin A deficient cytology sample, epithelial cells are enlarged and isolated with pyknotic nuclei and no goblet cells.<sup>18</sup> All stages between normal and deficient cytology may be seen, including a decrease in the number of goblet cells and enlargement of the epithelial cells. They are called marginal (borderline). This subclassification was not used in this study.

Children were classified as ICT normal if either of the two specimens had goblet cells and normal epithelial cell morphology, the same criteria used in the Chuukese study. Trachoma, a disease which can cause ICT readings and have a confounding effect on results, has not been diagnosed in the Marshall Islands.

## Results

All children ages three through ten living on the atoll were examined; the sample size was 38. The number, age, and gender distribution of the children in the study can be seen in Tables 1 and 2.

Prevalence rates were calculated using the number of cases as the numerator and the total number of children living on Mili atoll as the denominator. Forty-seven percent had xerophthalmia (5% with XN, 39% with XN + XIA, and 3% with XN + XIB). More

**Table 2**

	frequency	%
<b>Goblet cells</b>		
sufficient	7	65.8
deficient	25	18.4
no sample	6	15.8
<b>Total</b>	<b>38</b>	<b>100</b>
<b>Night blindness</b>		
no	32	84
yes	6	16
<b>Total</b>	<b>38</b>	<b>100</b>
<b>Vitamin A intake</b>		
adequate	12	32
deficient	26	68
<b>Total</b>	<b>38</b>	<b>100</b>
<b>Xerophthalmia</b>		
no	23	61
yes	15	39
<b>Total</b>	<b>38</b>	<b>100</b>

than three-quarters (78%) were ICT abnormal, indicating 31% of the population had mild subclinical vitamin A deficiency.

There was no significant age differences between children with and without xerophthalmia, with and without vitamin A intake, or those with and without night blindness.

Based on the nutrition survey, 86% of the children had not received the U.S. recommended daily allowance of 1,000 retinol equivalents of vitamin A in the previous week. The "typical" childhood daily diet on Mili consisted of six cups of white rice, four tablespoons of soy sauce, two six ounce sections of pandanus, 60-72 ounces of coconut juice, twelve ounces of coconut, and ten small bananas. One can of tinned meat (Spam, corned beef, or mackerel) was shared among 6-8 family members two to three times a week. Fresh fish was typically consumed twice a week. Papaya was eaten on an irregular basis, often an eight-ounce portion every four to five days.

In correlating vitamin A intake and xerophthalmia, the Spearman correlation coefficient was significant at .02 ( $p < .05$ ). However, in correlating intake with night blindness, the Spearman coefficient of .20 was not significant.

## Discussion

All eligible children in this isolated atoll participated in this study, providing a clear look at vitamin A deficiency in this setting. The first hypothesis was supported by the data with the prevalence of night blindness far exceeding the WHO standard. Age did not appear to be a factor in who experienced vitamin A deficiency, so the second hypothesis was rejected. Rather, the vitamin A deficient children tended to cluster within families. The soil has varying levels of residual radiation and the inhabitants of different atolls may have different levels of nutritional education, so the results should be generalized to the other atolls of the Marshall Islands with caution. However, these results are consistent with a 1995 study in the Republic of Kiribati. The coral atolls of Kiribati, 1,500 miles south, are similar to the Marshall Islands. The xerophthalmia rate of 23.6% in Kiribati is among the highest reported rates in the world,<sup>20</sup> and is only now exceeded by Mili's rate of 39%.

The power of the study is limited by the number of subjects. It is this and the limitations of the nutritional exam which may explain the lack of statistical significance between vitamin A intake and night blindness, the third hypothesis.

Prevalence rates of abnormal cytological findings are likely to be many fold that of clinical disease, drastically reducing sample size requirements.<sup>23</sup> Natadisastra's findings in 1988 indicate abnormal conjunctival impression cytology appears to be five to ten times more common than clinical disease in populations at risk.<sup>21</sup> It is a promising tool for assessing adequacy of vitamin A levels although the determination of status is hindered by the time lag between acute changes in serum levels and the resultant changes in epithelial differentiation. Following vitamin A treatment, impression cytology detects improvement in vitamin A status; however, areas of conjunctival chronic metaplasia on rare occasions fail to respond to improved vitamin A status.<sup>14</sup>

## Conclusions

With the World Health Organization's definition of a 1% prevalence of night blindness for a significant health problem, the 16% on Mili atoll indicated the seriousness of this issue. Inadequacy of vitamin A intake was the rule, not the exception, for the children of Mili. At the end of the data collection phase, treatment was provided with vitamin A 25,000 units to 78% of the children in the study for their clinical and sub-clinical vitamin A deficiency.

Vitamin A deficiency in the Marshall Islands appeared to be a previously unrecognized nutritional problem. Given the co-morbidity of vitamin A deficiency with diarrhea/dehydration, malnutrition, respiratory illnesses including pneumonia, and skin infections,<sup>27, 28, 29</sup> the high number of hospital admissions for those diagnoses is not surprising.

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## Notes

Dr. Dickson was a medical student at the time this study was carried out and Dr. Hunt was Associate Dean for Academic Affairs, both from the University of Washington School of Medicine.

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If you are too smart to pay the doctor,  
you had better be too smart to get ill!

**African proverb**