Original Article

Salt intake and iodine status of women in Samoa

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The objective of this study was to determine iodine nutrition status and whether iodine status differs across salt intake levels among a sample of women aged 18-45 years living in Samoa. A cross-sectional survey was completed and 24-hr urine samples were collected and assessed for iodine (n=152) and salt excretion (n=119). The median urinary iodine concentration (UIC) among the women was 88 µg/L (Interquartile range (IQR)=54-121 µg/L). 62% of the women had a UIC <100 µg/L. The crude estimated mean 24-hr urinary salt excretion was 6.6 (standard deviation 3.2) g/day. More than two-thirds (66%) of the women exceeded the World Health Organization recommended maximum level of 5 g/day. No association was found between median UIC and salt excretion (81 µg/L iodine where urinary salt excretion ≥5 g/day versus 76 µg/L where urinary salt excretion <5 g/day; *p*=0.4). Iodine nutrition appears to be insufficient in this population and may be indicative of iodine deficiency disorders in Samoan women. A collaborative approach in monitoring iodine status and salt intake will strengthen both programs and greatly inform the level of iodine fortification required to ensure optimal iodine intake as population salt reduction programs take effect.

Key Words: iodine, sodium, salt, urinary excretion, Samoa

INTRODUCTION

Iodine deficiency is recognised as a major preventable public health problem worldwide. Adequate dietary iodine intake is essential for the production of the thyroid hormones thyroxine (T4) and triiodothyronine (T3). Inadequate dietary iodine causes a broad spectrum of adverse health effects termed iodine deficiency disorders (IDD).[1,2] Severe iodine deficiency may cause hypothyroidism at all ages and in pregnant women may result in their offspring suffering impaired neurocognitive development and growth retardation.[3] Mild depression of mental ability along with assorted deficits in hearing, learning, and reproductive outcome can also ensue in a significant proportion of some populations.[3] Socioeconomic disadvantage may follow as iodine deficient communities are typically lower in intellectual attainment,[4] work output and per capita income.[5] The correction of iodine deficiency in a population is anticipated to reduce or eliminate all its consequences.[6]

In many areas of the world, including developing and developed countries, the natural diets do not provide adequate iodine.[7] With economic development, the transition from traditional to imported diets may exacerbate already low iodine levels through increased intake of more refined and processed foods with low or no iodine content.[8-10] Universal salt iodisation (USI), whereby all salt for human and animal consumption is iodised is the main proven intervention strategy for the control and elimination of IDD.[1] However, there is concern that recommendations for reducing salt intake could jeopardise further progress and conversely, the concern that advocacy for salt iodisation programs could reduce the impact of policies of salt reduction for preventing cardiovascular dis-

ease.[11] In the Pacific region, the level of salt consumption (iodised and non-iodised) is largely unknown and data on iodine nutrition is sparse.

The primary objective of the present study was to determine iodine nutritional status among a sample of women aged 18-45 years living in the Independent State of Samoa. A secondary objective was to investigate whether iodine status differed across salt intake levels.

MATERIALS AND METHODS
The data was derived from a cross-sectional survey done in the four regions (Apia Urban Area, North West Upolu, Rest of Upolu and Savaii) of Samoa between March and June 2013 as part of the Samoan Ministry of Health national non communicable disease risk factor survey, using the WHO STEPs approach to surveillance. Permission to undertake the study was given by the Ministry of Health Samoa and the Health Research Committee Samoa. Ethical approval was also sought from the Ethics Review Committee of the Western Pacific Regional Office of the World Health Organization and the University of Sydney Human Research Ethics Committee.

Participant recruitment
The standard WHO STEPs sampling methodology was used to identify a random sample of adults aged 18-64 years from the population based on the most recent census.[12] The STEPs sampling approach uses a stratified (province or division) three-stage (enumeration area, household and individual) cluster random sampling process. A list of randomly selected enumeration areas were identified from within villages with the probability of an enumeration area being selected that is proportional to the size of the enumeration area. Households were then randomly selected from within each enumeration area. This yielded a total number of 2,975 households. Then using the Kish method one person from every fifth household (so as to recruit 250 men and 250 women in total) was selected to collect a urine sample to assess salt intake (and iodine intake in women aged 18-45 years). The aim was to recruit 150-200 women. This would represent a sample of at least 5% of the female population of the 18-45 year old age group in Samoa.

Exclusion criteria
There were no exclusion criteria based on inter-current illness, use of medications or any other aspect of demography or personal history other than age.

Data collection
A Ministry of Health (Samoa) officer visited selected households, provided information on the survey to the selected individuals and invited their attendance at village data collection sites the following day. At house visits, the study was explained further and written consent was sought. For those individuals from whom consent was obtained, the WHO STEPs questionnaire[13] was completed and a 24-hr urine collection was requested.

A single 24-hr urine collection was obtained. The first voided urine upon waking on the day of collection was discarded and participants then collected all urine up to and including the first void the following morning. An aliquot from the 24-hr sample was then taken for urinary iodine assessment. Urine samples were stored at 2℃ in the National Health Service laboratory of Samoa before transportation to the Institute of Clinical Pathology and Medical Research (Sydney, Australia), where they were stored at -20℃ until assayed. The urinary iodine measurement was performed by ammonium persulfate digestion[14] prior to Sandell-Koltoff reaction in a microtitre plate format.[15,16] Urinary sodium was assessed using the indirect ion specific electrode method with the buffered kinetic Jaffe reaction without deproteinisation used for assay of urine creatinine. Suspected incomplete urine collections (i.e. urinary creatinine <4 mmol/day or a 24-hr urine collection of <500 mL) and over-collections (urinary creatinine >3 standard deviations from the mean) were excluded.
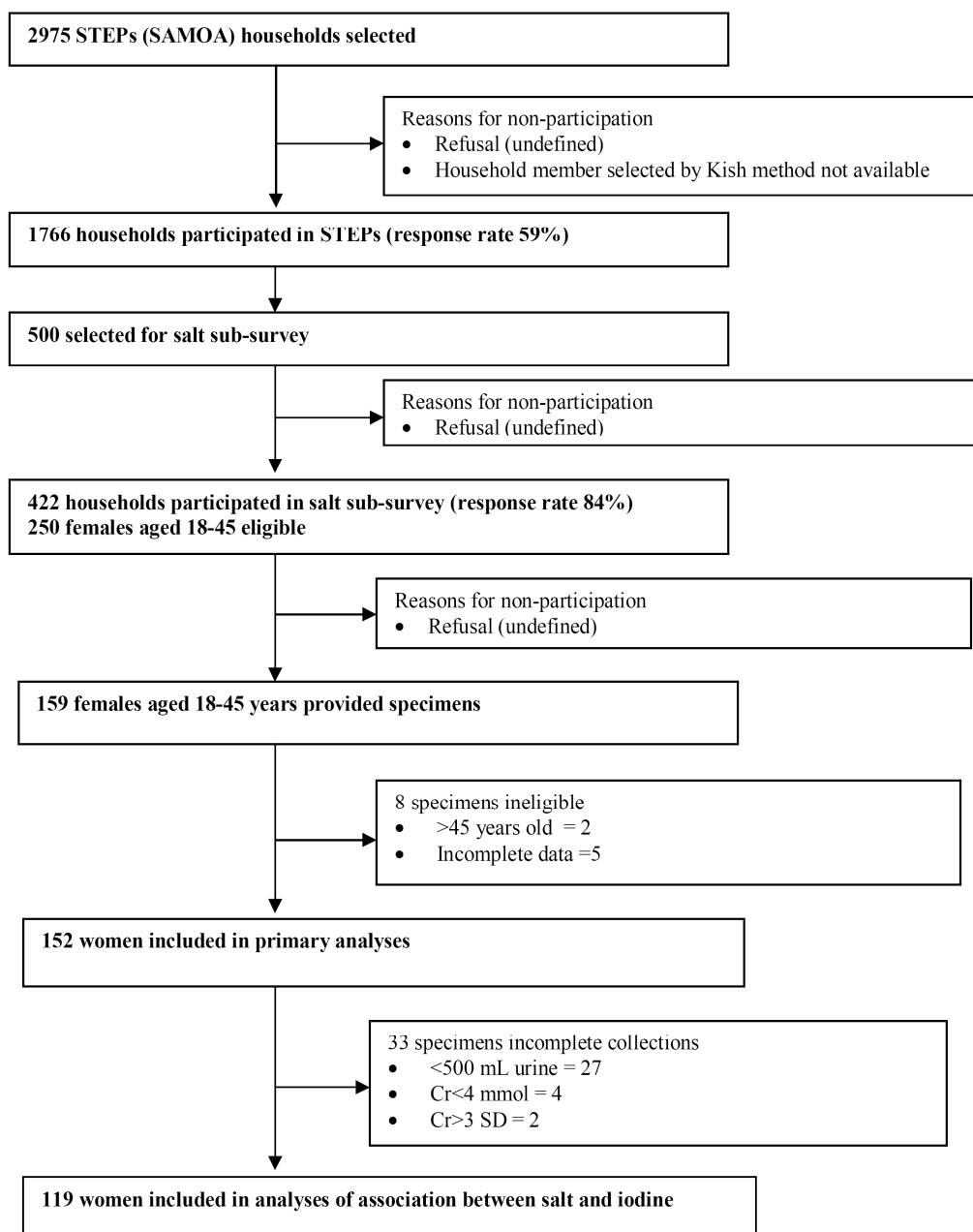
For each individual, the 24-hr sodium excretion value (mmol/day) was calculated as the concentration of sodium in the urine (mmol/L) multiplied by the urinary volume (L/day). The conversion from mmol sodium to grams salt was made by dividing by 17 and the conversion from sodium (Na) to salt (NaCl) by multiplying by 2.542. Urinary iodine excretion levels are expressed as the median urinary iodine concentration (UIC) and iodine deficiency or sufficiency nutritional status in the population assessed according to the reference values of the median UIC from the WHO and the International Council for the Control of Iodine Deficiency Disorders (ICCIDD) which state that a median UIC [≥100 μg/L represents adequate iodine nutrition in the population, reference value 150 mcg].[1] Daily dietary intake of iodine was estimated using two methods, the first by an adjusted body weight calculation (μg/L×0.0235×body weight (kg))[17] and the second by multiplying the concentration of iodine in the urine (μg/L) by the 24-hr urine volume (L)/0.90).[1] Both methods were used to determine the likely validity of the equations within this population.

Statistical analysis
Mann-Whitney U tests were performed to assess differences in UIC according to urinary salt excretion values of ≥5 g/day and <5 g/day. Regression models were also fitted to explore the association between daily urinary salt excretion and the urinary iodine excretion rate. All data were analysed using the SPSS statistical package (version 21: SPSS Inc, Chicago IL) with a significance level of 0.05.

RESULTS
Recruitment of the population sample is summarised in Figure 1 and participant characteristics are summarised in Table 1. One hundred and fifty-two women of 18-45 years from four regions of Samoa participated in the study. The mean age of participants was 31.5 (standard deviation 8.3) years. For the analyses of association between salt and iodine there were one hundred and nineteen individuals, with 33 excluded because of suspected incomplete urine collections, (27 excluded volume <500 mL/24-hr and 4 excluded creatinine <4 mmol/d), and a further 2 were excluded because of suspected over collection, creatinine >3 standard deviations above the mean).

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│ 2975 STEPs (SAMOA) households selected        │
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          │        ┌──────────────────────────────────────────────────────┐
          ├───────▶│ Reasons for non-participation                          │
          │        │  • Refusal (undefined)                                 │
          │        │  • Household member selected by Kish method not available │
          │        └──────────────────────────────────────────────────────┘
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│ 1766 households participated in STEPs (response rate 59%) │
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│ 500 selected for salt sub-survey              │
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          ├───────▶│ Reasons for non-participation              │
          │        │  • Refusal (undefined)                     │
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│ 422 households participated in salt sub-survey (response rate 84%) │
│ 250 females aged 18-45 eligible               │
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          │        ┌──────────────────────────────────────────┐
          ├───────▶│ Reasons for non-participation              │
          │        │  • Refusal (undefined)                     │
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│ 159 females aged 18-45 years provided specimens │
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          ├───────▶│ 8 specimens ineligible                     │
          │        │  • >45 years old  = 2                      │
          │        │  • Incomplete data =5                      │
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│ 152 women included in primary analyses        │
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          ├───────▶│ 33 specimens incomplete collections        │
          │        │  • <500 mL urine = 27                      │
          │        │  • Cr<4 mmol = 4                           │
          │        │  • Cr>3 SD = 2                             │
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│ 119 women included in analyses of association between salt and iodine │
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Figure 1. Recruitment of participants. Figure data shows the participant recruitment outcome as part of the Samoan STEPs survey.

Table 1. Participant characteristics

Participant characteristic	Urinary iodine analysis (n=152)	Analysis of association between salt and iodine (n=119)
Women (%)	100	100
Pregnant (%)	4.6	5.0
Breast feeding (%)	unknown	unknown
Age, years	31.5 (8.3)	32 (8.4)
Height, cm	162 (5.9)	161 (5.6)
Weight, kg	87 (21)	88 (22.1)
BMI, kg/m^2	33.3 (9.3)	34 (10)

Table data shows participant characteristics of the two analysis undertaken, presented in proportions and means and standard deviations.

Urinary iodine and salt excretion

The median UIC was 88 µg/L (interquartile range=54-121 µg/L). Two thirds (62%) of the women had UIC <100 µg/L. Estimating the daily iodine intake using the adjusted body weight calculation resulted in an estimated median daily excretion intake of 167 µg (IQR 102 µg-258 µg) but if daily iodine intake was instead estimated by multiplying measured urinary iodine concentration by 24-hr urine volume the estimated median daily iodine excretion was 61 µg (IQR 40 µg-93 µg). The distribution of

urinary iodine concentration assessed against the WHO/UNICEF/ICCIDD criteria for iodine nutrition[1] identified 44% of women as iodine deficient if the adjusted body weight calculation method was used but 91% if the calculation method was based upon 24-hr urine volume (Figure 2).

The estimated mean 24-hr urinary salt excretion for these females was 6.6 g/day (standard deviation 3.2) and 66% of individuals exceeded the World Health Organization recommended maximum level of <5 g/day (Figure 3).

Association of urinary salt excretion with urinary iodine excretion

There was no detectable difference in iodine intake in population subgroups defined by salt intake above or below 5 g/day. The median UIC was 81 μg/L in those consuming ≥5 g/day salt (n=78) compared to 76 μg/L in those consuming <5 g/day salt (n=41) (p=0.5). Regression equations identified no association between urinary salt and urinary iodine excretion regardless of whether daily iodine intake was estimated using the adjusted body

weight calculation method or based upon 24-hr urine volumes (both p=0.9).

DISCUSSION

The present study found that almost two-thirds (62%) of women of child bearing age (18-45 years), including pregnant and lactating women, had UIC <100 μg/L, indicating inadequate iodine nutrition. Iodine requirements are greatly increased during pregnancy and lactation, if these women were to fall pregnant at this level of mild iodine deficiency it could predispose the foetus to developmental deficits associated with maternal iodine deficiency.[18] Thus this deficiency may negatively impact health, quality of life and potentially hinder socio-economic development.

Until recently, iodine deficiency has not been considered a public health problem for the Pacific Island nations as it was believed the inhabitants of these islands would have ready access to iodine rich seafood. However, a recent assessment of children from the island of Tanna in Vanuatu observed a high prevalence of iodine deficiency
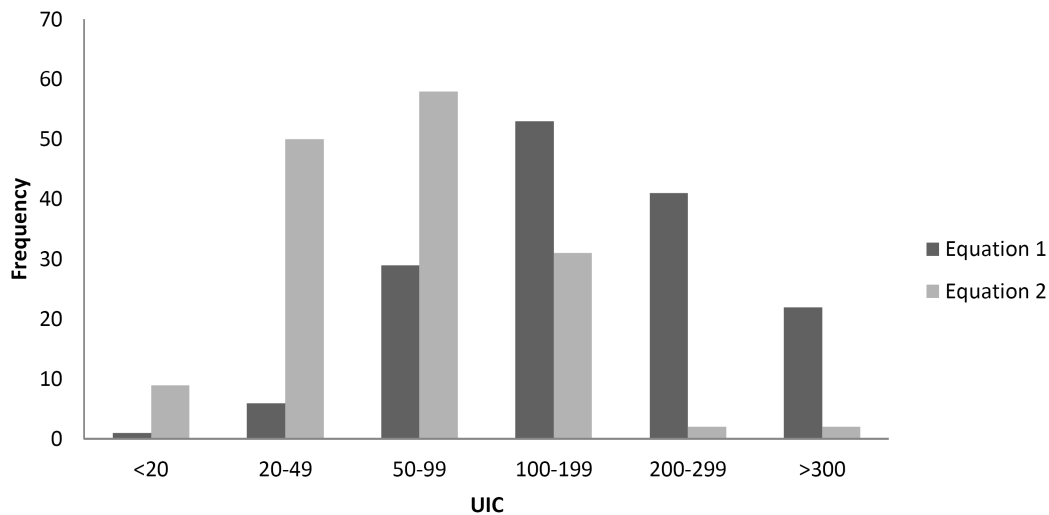
Figure 2. Frequency and distribution of urinary iodine excretion (UIE) estimates (μg/day) (n=152) using two different approaches to estimation. Figure data shows the frequency and distribution of UIC in the sample population calculated using equation 1 (μg/L) × 0.0235 × body weight (kg)) and equation 2 (μg/L) × 24-hr volume (L)/0.90)).
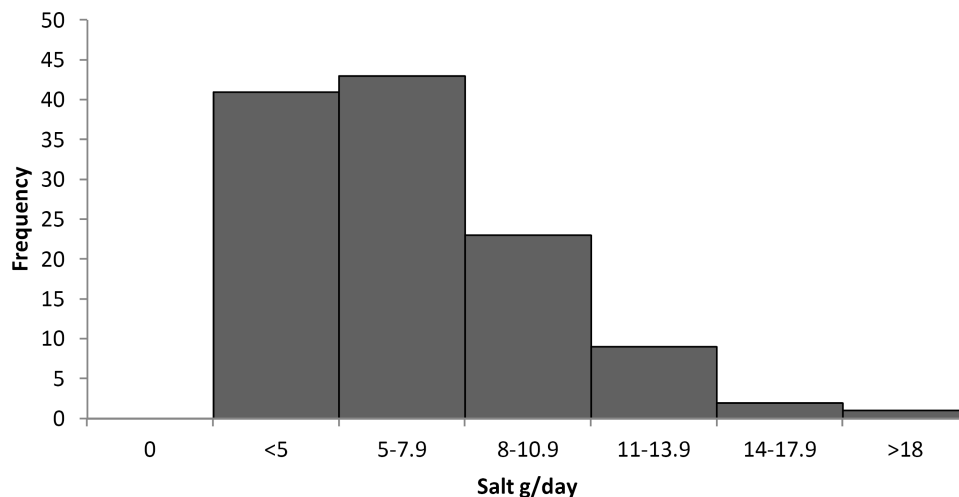
Figure 3. Frequency and distribution of urinary salt excretion levels (n=119). Figure data shows the frequency and distribution of urinary salt excretion in the sample population after excluding likely implausible urinary specimens.

dispelling the notion that the inhabitants of Tanna, at least, are not at risk of iodine deficiency disorders.[16] Our study provides further evidence that iodine deficiency is likely to be a problem in the Pacific region.

Ensuring that there are adequate levels of iodine in the food supply is an important public health intervention. Significant improvements in iodine nutrition have been made following the implementation of universal salt iodisation programs globally, however the strong government support required to develop public policy to ensure that all edible salt is iodised is often lacking. The current International Council for the Control of Iodine Deficiency Disorders (ICCIDD/UNICEF/WHO) guidelines recommend salt iodisation within the range of 20-40 mg of iodine per kg of salt.[1] Within this range, adult men and women satisfy their iodine requirements, based on the assumption of consuming 7.5 and 3.75 g/day respectively. The most vulnerable group - pregnant and lactating women, and children less than two years of age however will not be adequately covered by iodised salt where universal salt iodisation is not fully implemented.[11] Consequently it is recommended that in this group additional complementary strategies such as supplementation should be considered to ensure optimal iodine nutrition.[19]

While salt intake in this population was 6.6 g/day, exceeding the World Health Organization recommended target of 5 g/day, the observation that urinary iodine excretion did not differ between individuals with high and low urinary salt excretion values (equivalent to greater or lower than 5 g/day, respectively) this is not atypical and has been reported in similar studies in both Australia[20] and South Africa.[21] In the Samoan population, like many other populations, it is anticipated that much of the salt consumed is by way of processed foods and use of non-iodised discretionary salt.[22] This belief is supported by data which suggests an increase in imported food consumption in the Pacific Island Countries,[23] however, research into dietary consumption practices is worthy of consideration in future research. Much of the food is imported from countries including Australia and New Zealand[8] which do not subscribe to mandatory salt iodisation nor is there local legislation to prohibit the importation of non-iodised salt.

The examination of the iodine status in this population provides evidence in support of new government legislation prohibiting the importation of non-iodised salt. The legislation is expected to be passed in 2014. The draft regulation[24] states all salt for import into, and for use and sale in Samoa for processing of food and for direct human consumption shall be salt to which has been added potassium iodide or iodate, or sodium iodide or iodate or iodate equivalent to not less than 20 mg/kg and not more than 30 mg/kg of iodine, and will be labelled as "Fortified" or "Enriched" or "Iodized". The success of the mandate for optimising iodine intake however will be dependent upon on the regulation of iodine concentration. For instance, in the Philippines, in response to an increase in goiter rates from 3.5% in 1987 to 6.7% in 1993 among Filipino children seven years and older an Act for Salt Iodization Nationwide (ASIN Law) was passed in 1995.[25] Based on household salt monitoring with the rapid test kits, there was an increase in use of iodised salt from 24.8% in 1998 to 81.1% in 2008; however the salt iodine concentration determined by WYD spectrophotometry found that only 25.2% of the salt was adequately iodised. Nonetheless, the efforts of the Philippine government resulted in a lower rates of grade 1 and 2 goiter of 2.2% and 0.2% respectively, among children 6-19 years in 2008.[26]

At the same time as mandating for importation of iodised salt, the Ministry of Health Samoa is coordinating the implementation of salt reduction programs in line with recent international recommendations.[27] These two programs may be seen as paradoxical, as one advocates for reducing salt intake, while the other to use salt to prevent against iodine deficiency disorders. However, as contradictory as they appear, close coordination of the programs provides greater opportunities for pooling resources to monitor intake and to adjust the iodine content of salt as population salt consumption decreases. Together the two policies can also advocate for food reformulation with less salt but using salt which is fortified.

This study benefits from the use of the preferred method for sodium and iodine analysis. Most of the ingested iodine and sodium (~90%) is excreted in the urine, however, urinary excretion of both elements varies substantially between days and seasons[28-30] as a consequence of a circadian rhythm of excretion[31-33] and due to difference in fluid intake[34] and renal clearance.[35] Large number of repeat samples are required for precision[36] and the small sample size in this survey may limit not only the precision of measurements of salt and iodine excretion but also their association. The use of multivitamins and or iodine supplements in this population was not recorded, however it is very unlikely that these women would be taking supplements because of cost and poor availability. In this study, there is a discrepancy between dietary iodine intake estimated by two different methods, most likely the result of the average body weight of the participants, highlighting the need for further validation studies in this area.[37] Furthermore, the challenges in obtaining a complete urine collection may also bias results, although standard checks were applied for the completeness of specimens based on urine volume and creatinine excretion. The response rate for the salt sub survey was relatively high for surveys of this nature. The survey however, was established to obtain salt intake data from a representative sub sample of the overall STEPs sample and not specifically to obtain a representative sample of females aged 18-45 years for the iodine analysis. While the generalizability of the iodine and sodium results for women of child bearing age is likely, the homogenous study population compromises the direct generalizability of the study finding to the Samoan population as a whole. This is because there is evidence of an inverse association between daily salt excretion and age.[38] Age may also influence iodine status in adults, but research is inconsistent and reports both increasing[39,40] and decreasing[41] urinary iodine concentration with age. In addition, women tend to have a lower iodine status[40,41] and sodium intake[38] than men.

In conclusion, iodine consumption for women of childbearing age in this survey is inadequate, this may put the future generation at risk of developing iodine deficiency disorders. However given the limitations of this

survey further research is recommended to support the findings of this study. Nonetheless, a collaborative approach in evaluation of iodine status and salt intake will strengthen both programs and greatly inform the level of iodine fortification required to ensure optimal iodine intake as population salt reduction programs take effect.

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Original Article

Salt intake and iodine status of women in Samoa

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萨摩亚妇女盐摄入量与碘状况

该研究旨在确定萨摩亚 18-45 岁女性居民碘营养状况及碘状况是否随着盐摄入水平的不同而不同。采用横断面调查，收集 24 小时尿液样本，分析碘（n=152）和盐排泄（n=119）。女性尿碘浓度（UIC）的中位数为 88 μg/L（四分位间距（IQR）=54-121 μg/L）。62%的女性 UIC<100 μg/L。粗略估计 24 小时尿盐排泄量的均数为 6.6（标准差 3.2）克/天。超过 2/3（66%）的妇女尿盐排泄量超过世界卫生组织推荐的最高水平 5 克/天。UIC 的中位数和盐排泄之间无关系（尿盐排泄量≥5 克/天的人群碘水平为 81 μg/L，尿盐排泄量<5 克/天的人群碘水平为 76 μg/L；p=0.4）。萨摩亚妇女碘营养不足表明可能该人群有碘缺乏病。部门间的协作将加强在监测碘营养状况和盐摄入量两个项目和极大地告知碘强化所要求的水平，以确保人群减盐计划有效实施时有最佳的碘摄入量。

关键词：碘、钠、盐、尿排泄、萨摩亚