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Exposure To Pesticides And Food Packaging Materials And Bmi In Samoan Mothers And Children

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Abstract

Background: Growing evidence suggests that environmental chemicals, including certain pesticides and bisphenol A (BPA), may be linked to obesity because of their ability to disrupt metabolic functions. *Methods*: We conducted a community-based, cross-sectional survey of 319 non-pregnant mothers, ≥18 years old, with a child aged 2-<5 years in Samoa, a country with high obesity prevalence, understudied agricultural and residential pesticide use and BPA consumption from canned and packaged goods. We measured weight and height of the mother-child pair and interviewed mothers about their potential environmental exposures. Using multivariable logistic regression, we evaluated the association between pesticide and BPA exposure surrogates and weight status. *Results*: Among 319 mothers, 87.2% were overweight or obese (BMI≥26); among 314 children, 16.2% were overweight or obese (World Health Organization BMIz≥2). A total of 188 (59%) and 108 (34%) women reported home pest treatments with insecticides or herbicides, respectively. In adjusted analyses, we observed a borderline significant association (p=0.056) between herbicide use and higher maternal BMI; no associations were observed for other environmental exposures. Children who lived within 0-29 meters of a farm/plantation had lower odds of overweight/obesity. *Conclusion:* Our results suggest a possible link between herbicide use and higher maternal BMI as well as an association with proximity of home to a farm/plantation and lower BMI in children. Further research could incorporate biological or environmental sampling of pesticide and BPA exposure.

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Introduction

Obesity has become a worldwide epidemic. The highest increase in BMI from 1980 to 2008 for both females and males was found in the Pacific Islands by the Global Burden of Metabolic Risk Factor of Chronic Diseases Collaborating Group.[11] In addition, the Global Burden of Disease Study 2013 revealed that the Pacific Islands have some of the highest prevalence of obesity.[1]

One Pacific Island country that is of particular interest is Samoa, a country that has one of the highest obesity prevalence in the world.[1] The 2014 Samoan Demographic and Health Survey (DHS) estimated that 83% of Samoan women aged 15-49 years were classified as overweight or obese (BMI>25.0).[2] Obesity is associated with a decrease in life expectancy[3, 5], increase in medical care and costs[4, 5], and an increase in risk of non-communicable diseases (NCDs), such as cardiovascular disease, diabetes, and cancer.[5] To avoid these health risks, the Samoa Ministry of Health has been encouraging its citizens to participate in physical activity and limit their intake of salt, sugar, and foods with little nutritional value.[6] While nutritional content and physical activity are critical components of obesity, there are other less obvious factors that could be contributing to the epidemic.

The foods that we eat can contain a multitude of environmental chemicals depending on how the foods are cultivated and packaged. A large number of people who engage in agriculture use pesticides.[18] In fact, it is estimated that 5.6 billion pounds are used worldwide, and Samoa is no exception.[17, 18] For a country smaller than the size of Rhode Island, Samoa has 72 pesticides that are registered for use.[17, 25] Certain pesticides are endocrine disrupting chemicals (EDCs) and are considered obesogens for their ability to disrupt usual functions of metabolism, increase risk of diabetes, and promote weight gain.[9, 10] The occupational use of pesticides, residential use of pesticides, and living in close proximity to a farm that uses pesticides increase the potential for exposure through multiple pathways, which, in conjunction with other dietary and physical activity factors, may be contributing to the prevalence of obesity in Samoa.

In addition, in recent years, the Samoan diet has evolved to become more modernized with the introduction and increased importation of processed foods and beverages.[7, 13] Many of these foods are nutrient dense but low in nutritional content.[13] Most imported foods are packaged in cans or plastics, which are known to be lined with epoxy resin containing bisphenol A (BPA) or made with BPA.[8, 14, 15, 21] BPA is also regarded as an EDC and an obesogen, increasing the potential contributions to the obesity epidemic.[9, 14, 15]

There is an overall paucity of research on environmental exposures in the Pacific Islands, including Samoa. Assessing these environmental chemicals may give us a further understanding of underlying contributors to the obesity epidemic in Samoa, a country with high obesity prevalence and understudied agricultural and residential pesticide use. This cross-sectional study evaluates the association between environmental exposure to pesticides and food packaging materials and BMI in Samoan mothers and children.

Methods

Study Population

We conducted a community-based, cross-sectional survey of 319 convenience-sampled, non-pregnant mothers, aged ≥18 years with a biological child aged 2-<5 years in three census regions of the main island Upolu, Samoa. Although 319 mothers were surveyed, 314 children's observations were used, because 5 children did not meet the age criteria. Each child had to have, or have had, four Samoan grandparents. Ten villages were recruited to participate in the survey that lasted for 6 weeks from July 2015 to August 2015. These villages were chosen based upon the Samoan census regions: Apia Urban Area (AUA), Northwest Upolu (NWU), and Rest of Upolu (ROU), which represent an urban-rural continuum and increasing socioeconomic status. With the assistance of the Samoa Bureau of Statistics, each village's mayor or Ministry of Women and Community Development representative recruited participants by informing the community of the research project being undertaken in their village. The research team was allotted 2-5 days in each village and data was collected in a convenient, central village location.

Data Collection

Weight and height measurements of the mother and child pair were collected by trained investigators. Weight was measured to the nearest 0.1 kg using a Tanita HD 351 digital weight scale (Tanita Corporation of America, IL), and height was measured to the nearest 0.1 mm using a portable GPM anthropometer (Pfister Imports, New York, NY). Each measurement was collected in duplicate and averaged for analysis. Mothers were interviewed about their environmental exposures: whether insecticides and herbicides were used in and around their homes, their residential proximity to farms/plantations, if anyone in the family worked on a farm/plantation, and their frequency of consumption of canned goods and packaged foods (Table 2). Each mother answered the same dietary questions about their child's consumption patterns (Table 3). The frequency of each food item was calculated into consumption per week.

Mothers were also interviewed about potential covariates that could possibly be predictive of having a higher BMI: region, age, education, socioeconomic status, current smoking status, alcohol intake within the past 12 months, household income, household density, running water in the home, electricity in the home, number of minutes engaged in moderate/vigorous physical activity per day, cooking location, perception of family's financial ability to live comfortably, and community spirit (Table 1). Education was categorized as having completed elementary education and having had a high school education or higher. Socioeconomic status was calculated based on the possession of 18 household durable goods and categorized into 4 groups: 0-4, 5-9, 10-14, 15-18, which equated to low, medium, high, and very high socioeconomic status, respectively. Household income for last year was categorized as annual household income below $10,000 Tala and $10,000

Tala or more. Household density was measured by dividing the number of people per household by the number of rooms in the house. Three categories were made based on the distribution of results. Moderate/vigorous physical activity per day was measured by a series of self reported answers about mother's engagement in moderate and vigorous activities at work and during leisure time. Community spirit was cited as a significant predictor of obesity in another study, and, thus, was included in the analysis.

Statistical Analysis

Using Chi-square tests and multivariable logistic regression models, we evaluated the association between pesticide use and BMI (BMI, kg/m^2) of mother and child pairs and the association between consumption of canned goods and packaged foods and BMI of the mother and child pairs using BMI categories for Polynesian populations. The cutoff points for Polynesian BMI categories are adjusted to reflect known differences in body composition (higher lean mass per kilogram body weight) between Polynesians and individuals of other ethnicity, and therefore higher than the global World Health Organization (WHO) BMI cutoff points.[16] In adults, normal weight is considered to be BMI<26 kg/m^2, overweight is defined as BMI 26-32 kg/m^2, and having a BMI>32 kg/m^2 is considered obese.[16, 19] However, some variables in our analysis did not have any observations when stratified into categories. Therefore, to compensate for categories with no observations, overweight BMI and obese BMI categories were combined into one category. In this study, BMI z-scores were calculated for children, using the WHO growth standards: normal weight for children was defined as BMI z-score<2, whereas children who were overweight or obese were defined as having a BMI z-score≥ 2, following the WHO guidelines.[22]

The Chi-square tests showed that variables of running water in the home and electricity in the home had little variability between the normal weight and overweight/obese categories, and, thus, were not added to the multivariable model. STATA was used to run Fisher's exact test for variables with less than 5 observations in a cell. Spearman's correlation was used to verify if there were any variables that were highly correlated with each other at r=0.8. None of the variables were highly correlated.

All variables, except for running water and electricity in the home, from Table 1 were included in the multivariable model. Environmental variables were kept in the model, as these were the main variables of interest. Other variables with a p-value <0.1 were kept in the model. Therefore, the most parsimonious model included mother's age, child's age, mother's total daily physical activity in minutes, household density, family's socioeconomic status, and mother's current smoking status. P-values were identified as significant at p≤ 0.05.

With the sample size of 319 and an alpha of 0.05, the power of the study stands at 90%. All data analyses were conducted in SAS 9.4 and STATA.

Results

Maternal Demographic and Residential Characteristics

Three hundred nineteen Samoan mothers were included in this study. Maternal demographic and residential characteristics are shown in Table 1. There were 41 women who were normal weight and 278 women were overweight/obese based on Polynesian-adjusted BMI. Most normal weight women lived in Northwest Upolu, while those who were overweight/obese were evenly distributed throughout the three census regions. The average maternal age for normal weight women was 28.8 years, and the average maternal age for overweight/obese women was 34.7 years ($p<0.001$). The majority of mothers had an education of high school or higher (normal weight, 63.4%; overweight/obese, 60.8%), and most women were classified as having low or medium socioeconomic status.

Maternal Environmental Exposures

Maternal environmental exposures are shown in Table 2. Mothers reported insecticide and herbicide usage in or around the home in the past year. The prevalence of insecticide use was 56.1% and 59.4% in the normal weight and overweight/obese BMI categories, respectively. Overall, there was a significant association between BMI categories and insecticide use ($p=0.003$). The prevalence of herbicide use was 19.5% and 36.0% in the normal weight and overweight/obese categories, respectively, which was lower compared to insecticide use. There was a significant association between BMI categories and herbicide use ($p<0.001$).

Most women in the study, regardless of BMI category, reported living 0-<15 meters away from a farm/plantation. In the normal weight BMI category, the least number of people reported living more than 60 meters from a farm/plantation; the least number of people in the overweight/obese BMI category reported living 15-29 meters from a farm/plantation. The proximity of the home to farms/plantations did not differ significantly by BMI categories ($p=0.699$). The majority of women in the survey reported that no one in their family, whether it was themselves, their partner, or other family members, worked on a farm/plantation (BMI<26, 100.0%; BMI≥26.0, 95.3%); there was no association between family members working on a farm/plantation and maternal BMI status ($p=0.157$).

When looking at canned goods consumption and maternal BMI, most mothers consumed 1-6 canned goods per week regardless of BMI category. While overweight/obese mothers consumed more than 6 canned goods per week (29.5%) compared to normal weight mothers (22.0%), there was no significant association between BMI categories and canned goods consumption ($p=0.514$). There was little difference in frequency distribution and no significance in the frequency of packaged foods consumption between the two BMI categories ($p=0.971$).

Maternal Multivariable Logistic Regression

In the most parsimonious multivariable logistic regression model shown in Table 4, insecticide use was not a significant environmental exposure for higher BMI status in Samoan mothers in the adjusted model (p=0.244) compared to those who did not use insecticides although insecticide use was found to be a significant indicator of higher BMI status in the unadjusted model. After adjusting for confounders, mothers who used herbicides in the past year had 2.455 times the odds of being overweight/obese compared to those who did not use herbicides, an association that was borderline significant (p=0.056).

None of the proximities of the mother's home to a farm/plantation were significantly associated with the mother being overweight/obese in the adjusted regression model. Those who lived in a home that was 0-<15 meters and 15-29 meters from a farm/plantation had 0.840 and 0.384, respectively, times the odds of being overweight/obese than those who lived in a home that was located 60 or more meters away from a farm/plantation.

While canned goods and packaged foods consumption was not statistically significant, the consumption of these foods increased the odds of a mothers being overweight/obese. For mothers who consumed canned goods more than 6 times per week there was a 1.912 increase in odds of being overweight/obese compared to those who consumed canned goods less than once per week, which is a greater odds than consuming canned goods 1-6 times per week (OR=1.1). Mothers who consumed 1-6 packaged foods or more than 6 packaged foods per week also had increased odds of being overweight/obese (OR=1.6, OR=1.6, respectively) compared to those who consumed less than one packaged food per week, although the consumption of packaged foods was not seen as a significant risk factor even after adjusting for confounders.

Children's Demographic Characteristic

Three hundred and fourteen Samoan children were included in this study. There were 263 normal weight children and 51 children who were overweight/obese (Table 3). The average age for normal weight children was 3.4 years, and the average age for overweight/obese children was 3.1 years, which was statistically significant (p=0.030). Normal weight children and overweight/obese children's average total minutes of daily physical activity was 28.5 minutes and 28.1 minutes, respectively. No statistical significant was observed between children's BMI z-score categories and a child's average total minutes of daily physical activity (p=0.590).

Children's Environmental Exposures

Questions about environmental exposures were answered by the child's mother (Table 3). The prevalence of insecticide use in or around the child's home was 57% and 66.7% in normal weight and overweight/obese children, respectively. Overall, there was no significant association between child's BMI z-score categories and insecticide use (p=0.438). The prevalence of herbicide use in or around the child's home was 34.2% and 31.4% in the normal weight and overweight/obese children, respectively. There was no significant association between child's BMI z-score categories and herbicide use (p=0.861).

Most children lived 0-<15 meters from a farm/plantation in both BMI z-score categories while the least number of children lived 15-29 meters from a farm/plantation in both BMI categories. The proximity of the home to farms/plantations did not differ significantly by BMI z-score categories (p=0.194). The majority of children did not have a family member who worked on a farm/plantation (BMIz<2, 95.8%; BMI≥2, 98.0%). No association was observed between having family members working on a farm/plantation and child's BMI z-scores (p=0.449).

Children's consumption of canned goods and packaged foods were also surveyed. The majority of children from both BMI z-score categories consumed canned goods 1-6 times per week (BMIz<2, 52.5%; BMI≥2, 58.8%). The lowest number of children from both the normal weight and overweight/obese categories reported consuming less than one canned good per week (BMIz<2, 20.2%; BMI≥2, 15.7%). There was no significant association among frequency of canned goods consumption and child's BMI z-score categories (p=0.665). Similar to canned goods consumption, most children in both BMI z-score categories consumed 1-6 packaged foods per week (BMIz<2, 64.6%; BMI≥2, 58.8%), and the fewest number of children from both BMI z-score categories reported consuming less than one canned good per week (BMIz<2, 12.9%; BMI≥2, 17.7%). No significant association was observed among the frequency of packaged foods consumption and child's BMI z-score categories (p=0.624).

Children's Multivariable Logistic Regression

Although many of the children's exposure and demographic variables were not significant at the bivariate level, children's multivariable logistic regression model was built to assess if there are any trends that might be of interest in future research. In the most parsimonious multivariable logistic regression model (Table 4), neither insecticide nor herbicide use in or around the home was significantly associated with a higher child BMI z-score (p=0.990, p=0.490, respectively) compared to those who did not use either pesticides. Insecticide use had a null effect on overweight/obese children (OR=1.0), and herbicides use had a protective effect on overweight/obese children (OR=0.8).

Children who lived 0-<15 meters or 15-29 meters from a farm/plantation had 0.3 and 0.3, respectively, times the odds of being overweight/obese compared to children who lived more than 60 meters from a farm/plantation. These distances were significant after adjusting for confounders (p=0.020, p=0.043 respectively), while children who lived 30-59 meters from a farm/plantation did not observe a significant association with a higher BMI z-score compared to children who lived more than 60 meters from a farm/plantation (p=0.106).

Children's consumption of canned goods was not statistically significant in the adjusted model; however, children who consumed 1-6 canned goods per week had 1.7 times the odds of being overweight/obese compared to children who consumed less than one canned good per week. Those who consumed more than 6 canned goods per week had 1.1 times the odds of being overweight/obese compared to children who consumed less than one canned good per week.

Consumption of packaged foods presented a different trend. Children who consumed 1-6 packaged foods per week had 0.7 times the odds of being overweight/obese compared to children who consumed less than one packaged food per week (p=0.454). Those who consumed more than 6 packaged foods per week had 0.7 times the odds of being overweight/obese compared to children who consumed less than one packaged food per week (p=0.909).

Discussion

To our knowledge, this is the first study to assess exposure to pesticides and food packaging materials and BMI relationship in Samoa and the Pacific Islands. Other studies from around the world have found evidence that certain pesticide exposure may be endocrine disrupting chemicals (EDCs) and may be associated with weight gain.[9, 10, 26, 27, 28, 29] Large amounts of pesticides are used around the world.[26] In 2001, worldwide pesticides expenditures were more than $32.5 billion and pesticide use exceeded 5 billion pounds.[26] Hence, with such large amounts of pesticide use, the need to understand the potential human health effects of pesticide exposure is necessary in Samoa, an understudied country with high levels of obesity.

The link between food packaging materials, many which contain BPA, and obesity has also been studied worldwide. However, few Pacific Island countries aside from New Zealand and Australia, have studied this relationship. In this study, questions about food packaging materials were used as a surrogate to measure BPA exposure in Samoan mothers and children. BPA is of particular interest because of the high production of this chemical. In 2011, 10 billion pounds of BPA was produced to manufacture polycarbonate plastics and epoxy resins, which are generally used in food packaging and the linings of many canned goods.[12, 14, 21] We become exposed to BPA, because it leaches out from the epoxy resin or polycarbonate plastics and into our foods and drinks.[21] This chemical accumulates in the adipose tissue and can be passed from mother to fetus.[32] After the baby is born, infants can be exposed to BPA from breast milk, polycarbonate products, and the environment, compounding the exposure of BPA.[21] Researchers consider BPA to be an EDC, promoting weight gain and has been connected to obesity, diabetes, adverse neurobehavioral and reproductive effects, and cancer.[12, 14, 15, 29, 30, 31]

This cross-sectional study demonstrated complicated associations of pesticides and food packaging material exposure and BMI in Samoan mothers and their children. While insecticide and herbicide use in or around the home in the past year was significantly different between the mothers who were normal weight and mothers who were overweight/obese, these environmental exposures were not significant in the adjusted regression model. However, although not significant, the elevated risk in use of herbicides and higher BMI should be explored further to understand whether there is some biochemical association or whether the use of these items represents some underlying lifestyle difference.

Proximity to farm/plantation is an environmental risk factor that could increase mothers' exposure to pesticides. However, in our adjusted model, while none of the distances were significantly associated with higher BMI, those who lived

0-<15 meters and 15-29 meters from a farm/plantation saw a protective effect compared to those who lived 60 or more meters away from a farm/plantation. A closer distance may be protective, because of the potential healthy worker effect.[23] Homes that are closer to a farm/plantation may encourage family members to work the farm/plantation more often than if the farm/plantation was further away from the home. Moreover, those who engage in physical activity on a farm/plantation may expend a lot of energy, offsetting the weight gain effects from possible obesogenic chemicals.[24]

Maternal frequency of canned goods and packaged foods consumption was mainly not significant in the unadjusted or adjusted models. Maternal consumption of packaged foods was significantly associated with socioeconomic status only in unadjusted models (p=0.013). Although not significant, we did observe an increase in odds of higher maternal BMI when one or more canned goods and packaged foods were consumed per week, which should be explored further in future research. Consumption of canned/packaged foods was explored here without considering overall caloric intake, which should be taken into account in further investigations.

For children, none of the unadjusted environmental exposures were significantly different between normal weight children and overweight/obese children except for child's age. Normal weight children were older, and, in the adjusted model, they had decreased odds of being overweight/obese.

Insecticide and herbicide use in and around the home were not associated with higher BMI in children. However, we did observe significance in the proximity of a home to a farm/plantation. Children who lived in homes that were closer to a farm/plantation compared to one that was 60 or more meters away was protective from being overweight/obese. Families who have a farm/plantation that is closer may be more inclined to bring their children along rather than leave them at home, possibly unsupervised. Therefore, children may be playing outside during this time, offsetting the obesogenic effects of pesticide exposure. Additionally, these families may be more reliant on foods from the plantation, which might result in lower calories, more fruit, and vegetable rich diet for the children.

Child's frequency of consuming one or more canned goods had elevated odds of being overweight or obese, although these odds were not significant. Interestingly, the higher odds of being overweight and obese were children consuming 1-6 canned foods per week, while for mothers the higher odds were those who consumed more than 6 canned goods per week. This may have resulted from the mother who came with the child may not being the primary care giver, which is a possibility if the mother works during the day. Hence, she may not know exactly what her child consumes. Children who consumed one or more packaged foods per week showed to have protective effects compared to those who ate less than one packaged food per week after controlling for confounders. None of the packaged foods were associated with socioeconomic status. Reasons for why consuming more packaged foods would be protective needs further investigating.

There were some limitations in this study. Self-reported data was recorded for each participant, which is vulnerable to recall bias and social desirability bias. Mothers may not have been the ones who sprayed pesticides or they may not remember if pesticides were used in the past year. Social desirability bias may have influenced mothers to underreport the amount of canned goods and packaged foods that were being eaten by both the child and herself and physical activity may have been over-reported.

Additionally, over the years, more people have opted for less physically demanding occupations, and, thus, the number of men and women engaged in subsistence farming has decreased[20]. Consequently, since our surveying hours were during the times when some mothers worked, the mothers who took a day off to come to the health survey might not be the primary care taker of the child who was brought to the survey. Therefore, it is plausible that the mother does not have complete knowledge of her child's dietary intake. Moreover, the convenience sampling may not be representative of other mothers and children as some working mothers were not able to participate in the survey.

Different interpretations of farm and plantation may have resulted in misclassifications and ultimately non-significant associations. Participants may have interpreted farm/plantation as one that is owned by a corporation and may have excluded home gardens from their interpretation. Furthermore, the results do not corroborate the results from a study by Keighley et al. (2006) that showed that 80% and 30% of men and women, respectively, in Samoa worked on a farm.[20] More clarification should be implemented in future studies.

Future studies should incorporate indirect (i.e. dust sampling, dermal/clothing patches, air sampling) and or direct (i.e. blood or urine samples) measurements of environmental exposures to compliment the self-reported data. Objective measures would enhance the understanding of the association between exposure of pesticide and BPA through plastic packaging materials and obesity. Furthermore, more information about what kinds of pesticides were used in or around the home or on a farm/plantation should be gathered, as different types of pesticides have different active ingredients and biological effects. Figure 1 shows that there is a high importation of insecticides compared to other pesticides. However, while we have a general idea of what kinds of pesticides are being imported into the country, there is a lack of information about who is using what.[17]

Conclusion

To our knowledge, this is the first evaluation of environmental exposures of pesticides and BPA and obesity in Samoa. While there may be a potential relationship between herbicide use and consumption of canned goods and packaged foods and higher maternal BMI, all of the associations with environmental exposures were insignificant. For children, higher BMI was only significantly associated when their home was located 0-29 meters from a farm. Future research should explore these relationships and incorporate more precise environmental exposure sampling.

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Appendix

Table 1. Demographic and residential characteristics of mothers' BMI score (N=319).

Characteristic	**Normal weight** (BMI< 26.0) 41 (12.9)[a]	**Overweight & Obese** (BMI≥26.0) 278 (87.2)[a]	**p-value**
Region			0.453
Apia Urban Area	10 (24.4)	93 (33.5)	
Northwest Upolu	17 (41.5)	93 (33.5)	
Rest of Upolu	14 (34.2)	92 (33.1)	
Age	28.8 ± 8.2	34.7 ± 9.5	<0.001
Education level			0.748
Elementary	15 (36.6)	109 (39.2)	
High School +	26 (63.4)	169 (60.8)	
Socioeconomic Status			0.370
Low	19 (46.3)	117 (42.1)	
Medium	20 (48.8)	120 (43.2)	
High	1 (2.4)	29 (10.4)	
Very high	1 (2.4)	12 (4.3)	
Smoking history			0.072
Yes	5 (12.2)	79 (28.4)	
No	36 (87.8)	197 (70.9)	
Unknown	0 (0.0)	2 (0.7)	
Alcohol intake			0.999
Yes	9 (22.0)	61 (21.9)	
No	32 (78.1)	217 (78.1)	
Household income			0.716
Less than $10,000 Tala	34 (82.9)	216 (77.7)	
$10,000+ Tala	7 (17.1)	61 (21.9)	
Unknown	0 (0.0)	1 (0.4)	
Household density			0.059
<3 people per room	5 (12.2)	83 (29.9)	
3-5 people per room	19 (46.3)	108 (38.9)	
>5 people per room	17 (41.5)	87 (31.3)	
Running water in home			0.399
Yes	41 (100.0)	266 (95.7)	
No	0 (0.0)	11 (4.0)	
Unknown	0 (0.0)	1 (0.4)	

Electricity in home			0.701
Yes	41 (100.0)	277 (99.6)	
No	0 (0.0)	1 (0.4)	
Moderate/vigorous physical activity (min/day)	43.2 ± 96.5	27.8 ± 81.0	0.269
Cooking location			0.815
In the house	8 (19.5)	60 (21.6)	
In a separate building	12 (29.3)	93 (33.5)	
Outdoors	21 (51.2)	123 (44.2)	
Perception of family's money situation to live			0.553
comfortably	5 (12.2)	14 (5.0)	
Never	2 (4.9)	24 (8.6)	
Rarely	16 (39.0)	116 (41.7)	
Sometimes	14 (34.2)	99 (35.6)	
Often	4 (9.8)	24 (8.6)	
Always			
Village spirit			0.078
Low	2 (4.9)	5 (1.8)	
Medium	24 (58.5)	127 (45.9)	
High	4 (9.8)	73 (26.4)	
Extremely high	11 (26.8)	72 (26.0)	

[a]Percentages may not sum to 100% due to rounding.

Table 2. Frequency and percentages of maternal environmental exposure characteristics by maternal BMI (N=319).

	Normal weight (BMI<26.0) 41 (12.9%)[a]	**Overweight & Obese** (BMI≥26.0) 278 (87.2%)[a]	
Environmental Exposure Characteristics	**N (%)[a]**	**N (%)[a]**	**p-value**
Insecticide use in or around the home			0.003
Yes	23 (56.1)	165 (59.4)	
No	12 (29.3)	105 (37.8)	
Unknown	6 (14.6)	8 (2.9)	
Herbicide use in or around the home			<0.001
Yes	8 (19.5)	100 (36.0)	
No	26 (63.4)	170 (61.2)	
Unknown	7 (17.1)	8 (2.9)	
Distance between home and nearest farm/plantation			0.699
0 – <15 meters	14 (34.2)	110 (39.6)	
15 – 29 meters	8 (19.5)	33 (11.9)	
30 – 59 meters	9 (22.0)	66 (23.7)	
≥60 meters	6 (14.6)	47 (16.9)	
Unknown	4 (9.8)	22 (7.9)	
Farm/plantation occupation in family			0.157
Yes (self, partner, or other family members)	0 (0.0)	13 (4.7)	
No	41 (100.00)	265 (95.3)	
Frequency of canned goods consumption			0.514
<1 per week	10 (24.4)	52 (18.7)	
1-6 per week	22 (53.7)	144 (51.8)	
>6 per week	9 (22.0)	82 (29.5)	
Frequency of packaged foods consumption			0.971
<1 per week	15 (36.6)	99 (35.6)	
1-6 per week	24 (58.5)	163 (58.6)	
>6 per week	2 (4.9)	16 (5.8)	

[a]Percentages may not sum to 100% due to rounding.

Table 3. Frequency and percentages of children's environmental exposure characteristics by children's BMIz scores (N=314).

	Normal weight (BMIz <2) 263 (83.8)[a]	**Overweight & Obese** (BMIz ≥ 2) 51 (16.2)[a]	
Demographic and Environmental Exposure Characteristics	**N (%)[a]**	**N (%)[a]**	**p-value**
Region			0.112
Apia Urban Area	80 (30.4)	23 (45.1)	
Northwest Upolu	94 (35.7)	13 (25.5)	
Rest of Upolu	89 (33.8)	15 (29.4)	
Child's age	3.4 ± 0.8	3.1 ± 0.8	0.030
Socioeconomic Status			0.126
Low	118 (44.9)	16 (31.4)	
Medium	113 (43.0)	26 (51.0)	
High	25 (9.5)	5 (9.8)	
Very high	7 (2.7)	4 (7.8)	
Child's total minutes of daily physical activity	28.5 ± 4.1	28.1 ± 4.5	0.590
Insecticide use in or around the home			0.438
Yes	150 (57.0)	34 (66.7)	
No	101 (38.4)	15 (29.4)	
Unknown	12 (4.6)	2 (3.9)	
Herbicide use in or around the home			0.861
Yes	90 (34.2)	16 (31.4)	
No	160 (60.8)	33 (64.7)	
Unknown	13 (4.9)	2 (3.9)	
Nearest farm/plantation location			0.194
0 – <15 meters	106 (40.3)	17 (33.3)	
15 – 29 meters	36 (13.7)	5 (9.8)	
30 – 59 meters	62 (23.6)	12 (23.5)	
≥60 meters	37 (14.1)	14 (27.5)	
Unknown	22 (8.4)	3 (5.9)	
Farm/plantation occupation in family			0.449
Yes (any family member)	11 (4.2)	1 (2.0)	
No	252 (95.8)	50 (98.0)	
Canned goods consumption			0.665
<1 per week	53 (20.2)	8 (15.7)	

1-6 per week	138 (52.5)	30 (58.8)	
>6 per week	72 (27.4)	13 (25.5)	
Packaged foods consumption			0.624
<1 per week	34 (12.9)	9 (17.7)	
1-6 per week	170 (64.6)	30 (58.8)	
>6 per week	59 (22.4)	12 (23.5)	

[a]Percentages may not sum to 100% due to rounding.

Table 4. Logistic regression analysis assessing environmental exposures and other risk factors for higher maternal and child BMI.

Environmental variables and other risk factors	Maternal BMI OR (95% CI)	p-value	Child BMI OR (95%CI)	p-value
Insecticide use	0.602 (0.26 – 1.41)	0.244	1.005 (0.46 – 2.22)	0.990
Herbicide use	2.455 (0.98 – 6.17)	0.056	0.777 (0.38 – 1.59)	0.490
Distance to farm/plantation				
0-<15 meters vs. ≥60 meters	0.840 (0.24 – 3.00)	0.788	0.320 (0.12 – 0.83)	0.020
15-29 meters vs. ≥60 meters	0.384 (0.10 – 1.51)	0.171	0.291 (0.09 – 0.96)	0.043
30-59 meters vs. ≥60 meters	1.058 (0.31 – 3.65)	0.929	0.464 (0.18 – 1.18)	0.106
Mom: Canned goods				
1-6 per week vs. <1per week	1.059 (0.36 – 3.10)	0.917	-	-
>6 per week vs. <1per week	1.912 (0.56 – 6.49)	0.299		
Mom: Packaged foods				
1-6 per week vs. <1 per week	1.584 (0.63 – 3.95)	0.325	-	-
>6 per week vs. <1 per week	1.583 (0.28 – 8.87)	0.602		
Child: Canned goods				
1-6 per week vs. <1 per week	-	-	1.716 (0.65 – 4.54)	0.276
>6 per week vs. <1 per week			1.069 (0.34 – 3.35)	0.909
Child: Packaged foods				
1-6 per week vs. <1 per week	-	-	0.699 (0.27 – 1.78)	0.454
>6 per week vs. <1 per week			0.686 (0.22 – 2.10)	0.510
Mother's age	1.090 (1.04 – 1.15)	<0.001	1.029 (1.00 – 1.06)	0.088
Child's age	-	-	0.624 (0.42 – 0.94)	0.023
Mom's total daily PA min	0.996 (0.99 – 1.00)	0.067	-	-
Household density				
3-5 per room vs. 0-2 per room	0.179 (0.06 – 0.57)	0.004	-	-
6+ per room vs. 0-2 per room	0.240 (0.07 – 0.80)	0.020		
SES				
Low vs. Very high			0.265 (0.06 – 1.21)	0.087
Medium vs. Very high	-	-	0.428 (0.10 – 1.77)	0.241
High vs. Very high			0.295 (0.06 – 1.59)	0.156
Mom's current smoking status	2.428 (0.85 – 6.96)	0.099	-	-

Figure 1. Number of registered pesticides with the Samoa Ministry of Agriculture and Fisheries in Samoa as of June 2015.