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Leptospirosis in Hawai'i: A Retrospective Study within a Health Care System, 2010-2021

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Abstract

Leptospirosis is a worldwide zoonotic disease with diverse clinical manifestations, ranging from mild flu-like symptoms to a life-threatening illness. It is often misdiagnosed or underreported due to the non-specific and overlapping clinical presentations with other febrile illnesses. Hawai'i has the highest incidence of leptospirosis in the United States, but there is a paucity of data regarding recent incidence and the current leptospirosis trends in Hawai'i. The objective of this study was to determine the epidemiology of patients with leptospirosis at one of the largest health care systems in Hawai'i and to identify risk factors associated with the severe illness. A retrospective study was conducted on patients with clinically suspected or confirmed leptospirosis diagnosis from 2010-2021. Of the 164 patients identified during the timeframe, 81 were outpatients with mild illness and 83 were inpatients exhibiting a more severe infection. Patients with the severe infection had a higher frequency of abnormal laboratory tests, including abnormal electrolytes, kidney and liver function tests. This group was more likely to suffer from acute kidney disease, sepsis, and rhabdomyolysis. More cases of leptospirosis were observed in the drier summer months of Hawai'i, and there were more cases in the areas with heavier rainfall on the island of Kaua'i. Risk factors for severe leptospirosis included being Native Hawaiian/Pacific Islander and elevated body mass index. Further studies on leptospirosis may reveal how patients with the above risk factors may benefit from early detection and treatment, potentially leading to reduced disease severity, and decreased hospitalization length.

Abbreviations

ALT = alanine transaminase
AST = aspartate aminotransferase
BMI = body mass index
CDC = Centers for Disease Control and Prevention
eGFR = estimated glomerular filtration rate
ELISA = enzyme-linked immunosorbent assay
HPH = Hawai'i Pacific Health
IgM = immunoglobulin M
ICU = intensive care unit
MAT = microscopic agglutination test
NHOPI = Native Hawaiian and Other Pacific Islanders

Introduction

Leptospirosis is a zoonotic infection endemic in Hawai'i caused by bacteria in the genus *Leptospira*. Hawai'i has one of the highest reported incidence rates of leptospirosis in the United States, with 11.51 cases per 100 000 population between 2014 and 2020.[1] *Leptospira* organisms colonize the kidney of infected animals including cattle, pigs, and rodents. The urine excreted by infected animals contains live bacteria which contaminate water and soil. Leptospirosis occurs when leptospires invade the human body through mucous membranes or skin abrasions.[2] Known risk factors for contracting leptospirosis include occupational activities such as farming and recreational activities in freshwater.[3] Increase in leptospirosis cases is noted after periods of heavy rainfall likely due to the flushing of the bacteria in contaminated soil into streams, rivers, and fresh water bodies.[4,5] The clinical presentation of leptospirosis can range from a mild flu-like illness to a life-threatening disease with multi-organ failure.[6] Clinical diagnosis of this zoonotic illness is challenging due to the non-specific flu-like symptoms that overlap with other febrile illnesses.[7] Limited information is available on risk factors for severe leptospirosis. Hawai'i specific data are also limited and current leptospirosis trends in Hawai'i may be evolving due to changes in the climate, economy, and population density. The last published epidemiological study utilized data from 1999-2008, while the preceding study covered the period from 1974-1998.[3,8] This study aims to elucidate the epidemiological profiles of patients with leptospirosis who received care at a large multi-facility health care organization in Hawai'i during 2010-2021 and to identify risk factors associated with the more severe form of the disease.

Methods

This observational study reviewed the records of patients diagnosed with leptospirosis at health care facilities affiliated with Hawai'i Pacific Health (HPH) from January 1, 2010 to December 31, 2021. The following HPH facilities were involved in the diagnosis and care for patients with leptospirosis: 3 hospitals on O'ahu ranging from 126 to 243 beds, 1 hospital on Kaua'i with 72 beds, 15 outpatient clinics on O'ahu, and 5 on Kaua'i. Patients who were evaluated in an outpatient facility or who were hospitalized for less than 24 hours were defined as outpatient. Mild leptospirosis was defined as cases managed in the outpatient setting, whereas severe leptospirosis was defined as cases requiring

hospitalization. Patients were included if they had an inpatient or outpatient visit at an HPH facility during the indicated time period and if they fulfilled clinical diagnosis of leptospirosis. Patients not meeting the criteria of a positive diagnosis or clinical suspicion of leptospirosis at an HPH facility were excluded.

In this study, a clinical diagnosis of leptospirosis refers to signs, symptoms, and medical history consistent with leptospirosis infection, with or without supporting laboratory evidence. Confirmed patients with leptospirosis exhibited clinically compatible symptoms and tested positive or borderline positive in culture or serological tests (eg, positive microscopic agglutination test [MAT] titer > 1:100, borderline positive MAT titer = 1:100, reactive immunoglobulin M [IgM] enzyme-linked immunosorbent assay [ELISA], or indirect hemagglutination assay results). Serological tests were performed at the Hawai'i Department of Health. Patients suspected of leptospirosis demonstrated a clinically compatible illness with documented high-risk sources of exposure within 21 days prior to symptom onset and/or had leptospirosis-associated routine laboratory findings, but no serological evidence. These high-risk outdoor activities included occupational (eg, farming), recreational (eg, freshwater swimming, hunting), and habitational exposure to potentially contaminated freshwater, animals, soil, or mud.

Data were first extracted using International Classification of Diseases Version 10 (ICD-10) diagnosis code A27 for leptospirosis and/or positive test for leptospirosis and then manually reviewed for confirmation. Laboratory blood tests performed within 3 days following the initial visit at an HPH facility were considered. The following variables were extracted from the HPH electronic medical records: demographics, initial vital signs, hospitalization duration, laboratory test results, comorbidities, admission to the intensive care unit (ICU), intubation, dialysis, and use of vasopressor medications during hospitalization. This study was reviewed by the Hawai'i Pacific Health Research Institute and determined to be exempt from Institutional Review Board review.

Statistical analysis

The study population and demographic data were analyzed and described using medians with range, frequencies, and percentages. Chi-square test and Fisher's exact test were used to compare distributions of selected variables. A two-tailed *P*-value of <.05 was considered statistically significant. Multivariable logistic regression was used to evaluate the likelihood of developing severe disease after adjusting for sex, BMI, and race. Patients with missing data for any of the variables being analyzed were excluded from the analysis. All statistical analyses were performed using Stata IC, version 15.1 (StataCorp LLC, College Station, TX). Zip code shapefiles were obtained from the Hawai'i State Geoportal. These shapefiles were imported into Stata and merged with a dataset containing the number of cases per zip code. Heatmaps were then generated in Stata to visualize the geographic distribution of cases across zip codes, with color gradients representing case counts.

Results

The retrospective analysis identified 164 patients with confirmed or clinically suspected diagnosis of leptospirosis at HPH within the 12-year time frame. Among the study population, 50 patients had a confirmed diagnosis of leptospirosis, and 114 patients were considered clinically suspected cases.

The majority of the patients were White (54%), followed by Native Hawaiian or other Pacific Islander (NHOPI) (23%), Asian (17%), and others comprised of American Indian or Alaska Native, Black or African American, or unknown (6%) (**Table 1**). There were 85 cases reported in the summer months (May-September) and 79 cases occurred in the winter months (October-April) (**Figure 1**). By count, 105 cases (64%) resided on Kaua'i and 37 cases (23%) resided on O'ahu (**Table 1**). Cases were relatively evenly distributed across O'ahu (**Figure 2**). In contrast, the highest number of cases (n = 31) was reported on the windward side of Kaua'i (**Figure 3**). Potential sources of exposure were documented for 133 (81%) of identified cases. Recreational activities accounted for 102 cases (76%) that comprised mostly freshwater swimming; 21 cases (16%) were linked to occupational exposures mostly related to farming; 6 cases (5%) were connected to habitational exposures to canines and rodents; and 4 cases (3%) were associated with international travel to regions of high leptospirosis (**Table 1**).

The cases observed were predominately male patients (75%), and the patients' age ranged from 1-85 years with a median of 29 years. The most frequent signs and symptoms charted at the initial visit were fever (76%), headaches (45%), myalgia (39%), vomiting (35%), and chills (32%) (**Table 1**). The initial visit report included subjective symptoms described by the patient. Of the 164 patients, 35 (21%) were admitted to the ICU, 15 patients (9%) had hypotension and were treated with vasopressors, 10 (6%) had respiratory failure and underwent mechanical ventilation, and 7 (4%) had acute renal failure and were started on hemodialysis. Furthermore, 33 patients (20%) suffered from acute kidney disease, 25 patients (15%) had sepsis, and 8 patients (5%) experienced rhabdomyolysis (**Table 1**). One death was reported.

Eighty-one patients (49%) were managed as an outpatient with a mild infection and 83 patients (51%) were hospitalized. The median length of stay for the hospitalized group was 4 days, with a range of 2-41 days. There were notable differences between the initial vital signs and laboratory values of outpatient (mild) versus hospitalized (severe) patients with leptospirosis. Compared to the outpatient cases, hospitalized patients had a higher frequency of elevated temperature above 38.3°C (31% vs. 17%, *P*=.044), respiratory rate or tachypnea (35% vs. 5%, *P*=<.001), and hypotension (13% vs 0%, *P*=.001). Initial laboratory abnormalities that were more common in hospitalized patients were hyponatremia (46% vs. 29%, *P*=.049), hypocalcemia (49% vs. 7%, *P*<.001), reduced estimated glomerular fil-

Table 1. Demographics, Clinical Manifestations, Hospitalization-Associated Treatments, Case Distributions, Sources of Exposure, and Susceptibility among the 164 Patients with Leptospirosis, Hawai'i Pacific Health, 2010-2021

Characteristics		Patients (N = 164)	
		Median	Range
	Age	29	26
		Frequency	%
Sex	Male	123	75%
	Female	41	25%
Race	White	89	54%
	Asian	28	17%
	NHOPI	37	23%
	Others	10	6%
Symptoms	Fever	124	76%
	Headaches	73	45%
	Myalgia	64	39%
	Vomiting	57	35%
	Chills	52	32%
	Nausea	42	26%
	Diarrhea	37	23%
	Abdominal Pain	31	19%
	Fatigue	30	18%
	Arthralgia	10	6%
	Jaundice	6	4%
	Conjunctivitis	5	3%
Hospitalization n = 83	ICU Admission	35	21%
	Intubation	10	6%
	Dialysis	7	4%
	Pressors	15	9%
Complications	Acute Kidney Disease	33	20%
	Sepsis	25	15%
	Rhabdomyolysis	8	5%
Case Distributions based on Patient's Zip codes	Kaua'i	105	64%
	O'ahu	37	23%
	Maui	3	2%
	Hawai'i	6	4%
	Outside of Hawai'i	13	8%
Sources of Exposure and Susceptibility	Recreational	102	77%
	Occupational	21	16%
	Habitational	6	5%
	International Travel	4	3%

Abbreviations: ICU, intensive care unit; NHOPI, Native Hawaiian and Other Pacific Islanders

tration rate (eGFR) (56% vs. 9%, *P*<.001), hyperbilirubinemia (48% vs. 14%, *P*<.001), and elevated liver functions tests including aspartate aminotransferase (AST) (72% vs. 25%, *P*<.001) and alanine transaminase (ALT) (53% vs. 28%, *P*=.002). Patients who were hospitalized were more likely to be overweight defined as a body mass index (BMI) >25 (55% v 35%, *P*=.015) (**Table 2**)**.** Logistic regression to evaluate disease severity, controlling for sex, BMI, and race revealed that being female reduced the risk for severe disease (aOR=0.39, 95%Cl=0.017, 0.90), higher BMI increased risk (aOR=1.07, 95%Cl=1.01, 1.14), and being NHOPI increased risk (aOR=4.91, 95%Cl=1.85, 13.0) (**Table 3**)

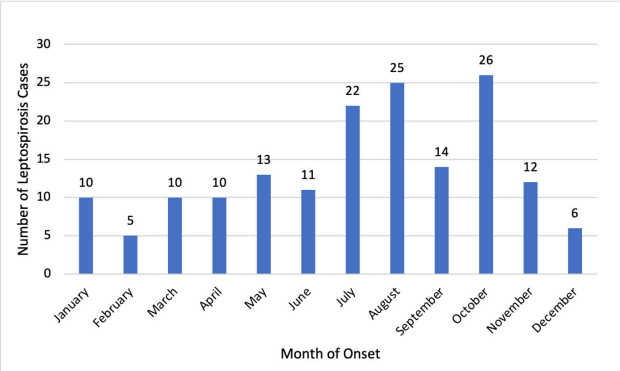

Figure 1. Monthly Distribution of Leptospirosis Cases, Hawai'i Pacific Health, 2010-2021

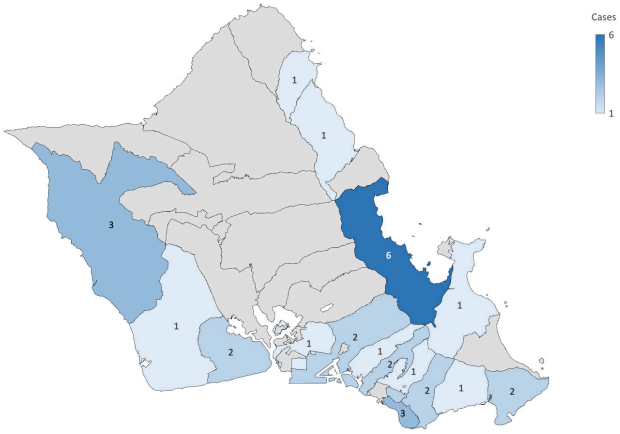

Figure 2. Distribution of Leptospirosis Cases on O'ahu, Hawai'i Pacific Health, 2010-2021

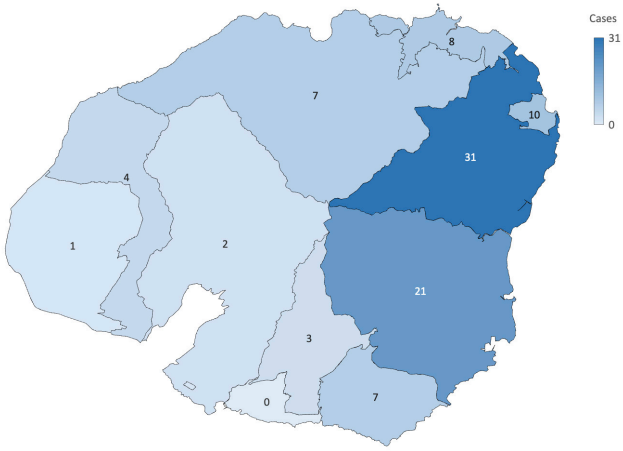

Figure 3. Distribution of Leptospirosis Cases on Kaua'i, Hawai'i Pacific Health, 2010-2021

Discussion

In this study, 164 patients met criteria for confirmed or clinically suspected leptospirosis between 2010 and 2021. For comparison, the Centers for Disease Control and Prevention (CDC) reported 1053 cases of leptospirosis nationwide, including 163 confirmed and probable cases in Hawai'i from 2014 to 2020. Puerto Rico reported the highest number of cases (n = 573), followed by Hawai'i (n = 163), California (n = 42), and New York (n = 38).[1] The number of cases identified in this study aligns closely with the burden reported in high-incidence areas such as Hawai'i, despite covering 5 additional years. This similarity may be due to limited access to case reports from the Hawai'i State Department of Health. According to CDC leptospirosis data from 2014 to 2020, the majority of cases occurred among individuals who identified as Hispanic or Latino (n = 402) and White (n = 280).[1] In contrast, the fewest cases were reported among Asian individuals (n = 7) and NHOPI (n = 2). This study and CDC surveillance data both demonstrate the predominance of White individuals among cases of leptospirosis. The differences in rates among Asian and NHOPI groups are likely attributed to the high number of cases reported from Puerto Rico.

This study demonstrated that a substantial number of patients with leptospirosis required life-sustaining treatments in the ICU admission. In this study, 21% of patients with leptospirosis received ICU-level care. This represents a higher rate of critical illness compared with the historically reported 5-10% of patients who develop severe, potentially fatal multiorgan dysfunction according to the CDC.[9] Using CDC surveillance data from 2014 to 2020 (n = 1053 cases), Atherstone et al in 2025 reported that among cases with available outcome data (n = 709), 85% (606 patients) were hospitalized and the mortality rate was 10%.[1] It is possible that patients with a milder form of the disease in this study are not presenting for care and are recovering without treatment. This would create a distorted picture of disease severity in the overall population by underestimating the mild cases. It is also possible that patients with severe symptoms may have presented at an advanced stage of the disease and therefore resulting in a higher rate of comorbid conditions and complications.

Leptospirosis is a biphasic illness with early symptoms mimicking many other acute febrile illnesses. Failure in early detection and treatment increases the risk of progression to life-threatening disease.[10] Finally, it is possible that higher ICU admission rate is indicative of more virulent serovars in the community. Notably, there was only 1 death associated with leptospirosis in this study which may indicate the overall improvement in general treatment and management of critical illness.

A few interesting risk factors were identified in this study. NHOPI were at a higher risk for severe leptospirosis compared with non-NHOPI groups. Previous studies have reported that NHOPI have higher obesity and chronic health condition rates in comparison to non-Hispanic Whites and Asian Americans.[11,12] The high prevalence of pre-existing chronic conditions could be the reason why this patient population is more susceptible to severe leptospirosis. It is also possible that this population is not accessing medical care during the early stages of the illness when symptoms are mild and more treatable. It is well-established that NHOPI patients are less likely to access

Table 2. Sex, Race, Abnormal Initial Vitals, and Laboratory Findings between Mild and Severe Leptospirosis Infections, Hawai'i Pacific Health, 2010-2021

		Mild (N = 81)		Severe (N = 83)		
		Frequency	%	Frequency	%	*P*-value
Sex	Male	62	70%	61	80%	.148
	Female	26	30%	15	20%	
Race	White	52	64%	37	45%	.012
	Asian	15	19%	13	16%	
	NHOPI	12	15%	25	30%	
	Others	2	3%	8	10%	
Abnormal Initial Vitals	Temperature (>38.3°C)	13	17%	25	31%	.044
	Respiratory Rate (>20)	2	5%	28	35%	<.001
	Mean Arterial Pressure (<65 mm Hg)	0	0%	11	13%	.001
	BMI (>25kg/m^2)	23	35%	44	55%	.015
Laboratory Findings	Neutrophilia	23	42%	47	57%	.147
	Lymphocytopenia	23	42%	47	41%	.115
	Anemia	8	15%	38	47%	<.001
	Thrombocytopenia	13	23%	64	78%	<.001
	Hyponatremia	16	29%	38	46%	.049
	Hypocalcemia	4	7%	40	49%	<.001
	Low eGFR	4	9%	30	56%	<.001
	Hyperbilirubinemia	7	14%	39	48%	<.001
	High AST	13	25%	60	72%	<.001
	High ALT	14	28%	44	53%	.002

Abbreviations: ALT, alanine transaminase; AST, aspartate aminotransferase; BMI, body mass index; eGFR, estimated glomerular filtration rate; NHOPI, Native Hawaiian and Other Pacific Islanders

Table 3. Adjusted Odds Ratio of Factors Predictive of Severe Leptospirosis, Hawai'i Pacific Health, 2010-2021

Variables	aOR	[95% CI]
Sex (Female)	0.39	[0.16, 0.90]
BMI	1.07	[1.01, 1.14]
Primary Race		
White	1	Reference
Asian	1.37	[0.52, 3.61]
NHOPI	4.91	[1.85, 13.04]
Other	4.03	[0.69, 23.43]

*Adjusted for sex, BMI, and race
Abbreviations: aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; NHOPI, Native Hawaiian and Other Pacific Islanders

care due to cultural and/or socioeconomic barriers.[13] Outreach directed toward NHOPI populations to disseminate leptospirosis information and provide early diagnostic testing could serve to improve outcomes. Elevated BMI was also a risk factor for more severe leptospirosis. Further studies to elaborate on these risk factors may aid in early detection and treatment, minimize leptospirosis severity, and decrease the length of stay and hospitalization costs.

Females were at reduced risk of severe leptospirosis and of leptospirosis in general. Several studies have shown that men are associated with having a higher leptospirosis incidence due to higher outdoor and occupational exposure.[14, 15] However, occupational exposure in this study only represents a small portion of exposure sources, with recreational activities being predominant.

It is not surprising that inpatients have a more severe form of leptospirosis evidenced by a higher rate of complications and laboratory test abnormalities. Severe leptospirosis is characterized by multi-organ dysfunction that requires intensive life-saving treatments. The results are compatible with other studies detailing the severe infection of leptospirosis. A greater portion of hospitalized patients suffered from tachypnea (35% vs 5%) and hypotension (13% vs 0%) than non-hospitalized patients. Tachypnea is a common signs of respiratory distress in severe leptospirosis, and hypotension could lead to pulmonary complications and renal failure.[16,17] The high frequency of initial laboratory test abnormalities in hospitalized patients also corroborates with other studies. Thrombocytopenia was frequently reported at the time of hospital admission for severe leptospirosis. A significant increase in total bilirubin and low level of hemoglobin was correlated with thrombocytopenia-associated hospital admission.[18] A modest increase in liver enzymes, AST and ALT, and disproportion-

ately elevated total bilirubin levels were noticed at the time of hospitalization in patients with severe leptospirosis.[19]

There are only 2 seasons in Hawaii's climate: warm, dry summer (May-September) and cooler, wet winter (October-April). Rainfall and rainstorms are more prevalent during the winter months.[20] Throughout this 12-year period, the cases were about equally distributed between wet and dry seasons with slightly more cases noted in the drier months (85 cases vs 79 cases). Previous studies conducted in tropical regions similar to Hawai'i demonstrated cases of leptospirosis at its peak during the rainy seasons.[21,22] Based on the results, the highest incidence of leptospirosis cases occurred from midsummer to early winter (July-October). Greater cases in the drier summer months may be attributed to an increase in recreational activities. This differs from the study by Katz et al in 2011 in which most cases occurred during the wetter winter months.[3] However, Katz et al in 2002 reported that cases of leptospirosis were more frequent during the summer months in Hawai'i.[8] Thus, patients and providers should remain vigilant throughout the year as seasonality does not appear to be a major factor in developing leptospirosis in Hawai'i.

In this study, most of the cases occurred in Kaua'i residents as opposed to O'ahu residents. This may be caused by the abundance of animal reservoirs, greater rural areas, popularity of freshwater recreational activities, and copious rainfall on Kaua'i compared to the other Hawaiian Islands.[23,24] Feral swine, a widespread invasive species, and cattle tend to reside in regions with nearby water sources on Kaua'i.[25] The Kaua'i leptospirosis outbreak in 1987 revealed half of the cattle near the outbreak site tested positive for *Leptospira*.[23] Swine, cattle, and other animal reservoirs can contaminate water systems and as a result, leptospirosis would then be transmitted to humans who engage in freshwater recreational activities.

There are a large number of cases in the areas with heavier rainfall on Kaua'i, which differs from the equal case distributions throughout O'ahu. Most cases were reported on the wetter windward side of Kaua'i and O'ahu. Hawaii's changing climate reveals increasing temperature and declining rainfall. The observed number of hot days and warm nights increased substantially during 2015 to 2020. The precipitation rate in the winter season decreased remarkably since 2007.[26] Climate change may influence the maintenance host's environment such that it affects the spread of this zoonotic disease.

Limitations

This study was limited by the small sample size inherent to the design of this hospital-based investigation. Past studies analyzed the leptospirosis case investigation reports from the Hawai'i State Department of Health.[3,8] These reports contained every leptospirosis case that was identified in the state. In this study, only patients from HPH facilities were included, which limited the detailed analysis of the impact of comorbidities on leptospirosis severity. Since HPH facilities are located solely on the islands of O'ahu and Kaua'i, it is not possible to grasp a full understanding of leptospirosis trends on the other Hawaiian Islands. Given the retrospective nature of this study some values were missing for clinical variables. Furthermore, it is possible that patients with the subclinical or mild form of the disease never sought medical treatment and the illness was unreported. This introduces a selection bias into the study, such that the more severe illness is depicted as opposed to all cases of leptospirosis representative of the population and may have increased the rate of severe forms of illness in this report.

Conclusion

This study identified NHOPI and elevated BMI as risk factors for the severe form of leptospirosis. NHOPI may have a higher risk due to other comorbid conditions or this result may represent delays in presenting for care early, when illness is mild. It is important for patients to seek medical care early on to reduce the potential for life-threatening outcomes especially if they have one of the risk factors for severe disease. Outreach to the NHOPI community regarding leptospirosis could decrease the morbidity of the illness. Furthermore, the seasonal peak of cases has recently shifted towards the late summer and early winter, rather than that of the wetter winter months in the previous 10-year study of 2011.[3] Although leptospirosis has been associated with heavy rainfall, this association may be dependent on the exposing activities. In many other countries, farming is the prevailing mode of exposure. In Hawai'i, recreational activities occur year-round due to the state's mild tropical climate and consistently favorable environmental conditions.[27] Future studies should analyze the difference in time from the exhibition of symptoms or presumed exposure to the initial health care visit. In addition, investigating a larger statewide and Pacific region dataset would further improve the comprehension of seasonal and geographical influences on leptospirosis and risk factors.

Conflict of Interest

None of the authors identify a conflict of interest.

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Associations Between Mental Health Status and Sleep and Physical Activity Among Adolescents in Hawai'i

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Abstract

This study examined associations between mental health status, physical activity, and sleep among Hawai'i adolescents using data from the 2017-2021 Hawai'i State High School Youth Risk Behavior Survey (YRBS). Mental health outcomes included feelings of sadness/hopelessness and suicidality. Logistic regression models assessed associations between physical activity, sleep, and mental health outcomes, adjusting for covariates including race, bullying, and the COVID-19 pandemic. Sleep duration, sleep location, and physical activity were significantly associated with mental health outcomes. Adolescents who slept longer were less likely to report sadness/hopelessness (6-7 vs. 0-5 hours: adjusted odds ratio [aOR]=0.59, 95% confidence interval [CI]=0.52-0.67; 8+ vs. 0-5 hours: aOR=0.36, 95% CI=0.32-0.41) and suicidality (6-7 vs. 0-5 hours: aOR=0.64, 95% CI=0.54-0.76; 8+ vs. 0-5 hours: aOR=0.38, 95% CI=0.31-0.46). Adolescents without a stable place to sleep had higher odds of suicidality (aOR=1.69, 95% CI=1.29-2.21). Physical activity was also protective; adolescents active for 6-7 days per week had lower odds of sadness/hopelessness (aOR=0.75, 95% CI=0.65-0.87) and suicidality (aOR=0.71, 95% CI=0.61-0.83) compared with those active 0-2 days. Boys had lower odds of both outcomes than girls. Compared with Whites, Filipinos, other Asians, and Pacific Islanders had lower odds of suicidality. Adolescents surveyed during the COVID-19 pandemic had increased odds of sadness/hopelessness. These findings underscore the importance of adequate sleep and physical activity for adolescent mental health, highlight the unique experiences of Hawai'i adolescents, and underscore the need to identify disparities among major adolescent groups to inform mental health prevention and intervention strategies.

List of Abbreviations

aOR = adjusted odds ratio
AUC = area under the receiver operating characteristic curve
BMI = body mass index
CDC = Centers for Disease Control and Prevention
MAR = missing at random
OR = crude odds ratio
YRBS = Youth Risk Behavior Survey

Introduction

In recent years, mental health problems and suicidality among adolescents have increased rapidly.[1-3] The percentage of adolescents reporting various mental health issues has steadily risen, reaching unprecedented levels. In 2021, over 40% of high school students in the United States reported experiencing persistent feelings of sadness or hopelessness.[4] Numerous factors have been investigated as potential intervention and prevention measures for adolescent mental health.

Research indicates that inadequate sleep is a significant factor affecting the mental health of individuals across all age groups.[5-7] This relationship is especially evident among adolescents,[8] with the majority of high school students (72.7%) reporting less sleep than the nationally recommended amount of 8 hours.[9] As adolescents transition to adulthood, various changes such as earlier school start times, increased late-night activities, and delayed sleep phases-contribute to sleep deprivation.[6] These changes significantly affect the quality and quantity of sleep adolescents receive each night.

Another known factor contributing to negative mental health outcomes is physical inactivity and a sedentary lifestyle.[10] Numerous studies have demonstrated the association between sedentary behaviors, including physical inactivity and excessive screen usage, and mental health issues such as anxiety, depression, and suicidality.[11,12] This is particularly relevant for adolescents, as 81% of those aged 11-17 globally are insufficiently active.[13]

Previous studies have analyzed adolescent mental health using the Youth Risk Behavior Surveillance System.[14] However, Hawai'i adolescents, characterized by a high percentage of minorities and diverse racial backgrounds, have not been extensively studied. In 2023, Joseph et al found significant associations between lack of sleep and suicide risk among minority adolescents, particularly among Black and Hispanic youth.[15] However, the National Youth Risk Behavior Survey (YRBS) combines all Asians into one racial category and does not disaggregate Asian ethnicities important to Hawai'i (eg Filipinos), limiting detailed comparisons and obscuring health disparities among the state's diverse youth population. Consequently, national statistics may not accurately reflect the mental health patterns of adolescents in Hawai'i.

Additionally, the negative effects of the COVID-19 pandemic exacerbated mental and physical health issues among adolescents due to lockdowns, distance-learning, and reduced social interaction.[16,17] Adolescents in Hawai'i may have experienced heightened feelings of isolation due to the state's geographic remoteness, despite its mild tropical climate, which allows for year-round outdoor physical activity. The pandemic may have impacted their physical

activity levels, and in turn, mental health. Analyzing post-COVID-19 data at the state level could help fill this research gap and provide deeper insight into the unique experiences of adolescents in Hawai'i.

In the current study, Hawai'i State YRBS data were utilized to evaluate the associations between mental health status, physical activity, and sleep among Hawai'i adolescents, as well as to compare mental health status before and after the COVID-19 pandemic. The findings of the study will help identify disparities among various major racial groups and illuminate the unique experiences of adolescents in Hawai'i.

Methods

Data Source

Hawai'i State-Level High School YRBS data from 2017, 2019, and 2021 were utilized. The Hawai'i YRBS is a joint effort of the Hawai'i State Department of Education, Department of Health, and University of Hawai'i Curriculum Research & Development Group, in collaboration with the Centers for Disease Control and Prevention (CDC). The YRBS collects information on health-risk behaviors that contribute to the leading causes of death and disability among youth and young adults. Traditionally, it has been a paper-pencil survey administered to Hawai'i public school students every other year. In 2021, the survey transitioned to a hybrid format, allowing schools to choose between pencil-and-paper or online administration.

The Hawai'i YRBS sample is selected using a two-stage, stratified random sampling method, considering the overall analysis weight, sampling strata, and primary sampling unit. Detailed information about the survey design and sampling method can be found on the YRBS website.[4] Deidentified Hawai'i data with disaggregated racial information was obtained from the Hawai'i Health Data Warehouse under a data use agreement. This study was approved by the University of Hawai'i Institutional Review Board under the "non-human subjects" category (#2024-00657).

Variables

Dependent variables. Two primary mental health indicators, both binary, representing a "yes" or "no" were included. The first question asked whether the respondent had ever felt "so sad or hopeless almost every day for 2 weeks or more in a row that [they] stopped doing some usual activities" in the past 12 months. The second question inquired if the respondent had "ever seriously consider[ed] attempting suicide" in the past 12 months.

Independent variables. Sleep variables included the number of hours of sleep on an average school night and the usual location of sleep in the past 30 days. The amount of sleep was categorized into 3 groups: 0-5 hours (sleep-deprived), 6-7 hours (insufficient), and ⩾8 hours (optimal), based on the recommendation that high school students should get 8-10 hours of sleep.[18,19] The sleep location question asked where respondents had slept during the past 30 days. It was categorized into 2 groups: a parent or guardian's house vs. other locations. Other locations included the home of a friend, family member, or others; shelter or emergency housing; motel or hotel; car, park, campground; or having no usual place to sleep. This variable served as a proxy for homelessness and family instability.

Physical activity was categorized into 3 groups: 0-2 days (low activity), 3-5 days (moderate activity), and 6-7 days (high activity). These categories were defined to approximate adherence to the US Physical Activity Guidelines for Americans, which recommend at least 60 minutes of moderate-to-vigorous physical activity daily for adolescents.[20]

The timeframe for before and after COVID-19 was determined by the year of the data: 2017 and 2019 data were considered pre-COVID-19, while 2021 data was classified as post-COVID-19. The YRBS is normally conducted every odd year during the spring (January-June). However, due to the COVID-19 pandemic, including the transition to virtual and hybrid learning and ongoing school closures in spring 2021, the 2021 YRBS was postponed and administered in fall (September-December) of that year.

Covariates. Demographic variables included sex, grade level, body mass index (BMI), and race. Sex was a binary variable, with values "boy" and "girl." Grade level had 4 categories, corresponding to each grade from 9th to 12th grade. BMI percentile was calculated based on sex, height, and age and categorized into 3 groups: underweight (<5th percentile), healthy weight (5th to <85th percentile), and overweight (⩾85th percentile).[4] Race data from the Hawai'i Department of Health included American Indian/Alaska Native, Black, White, Filipino, Japanese, Native Hawaiian/Part Hawaiian, Pacific Islander, Other Asian, and other racial groups. Based on observed similarity in mental health associations in the present study and prior literature on mental health disparities,[21,22] categories were collapsed into White, Filipino, Other Asians, Native Hawaiian, Pacific Islander, and Other.

Additional variables included bullying[23] and eating breakfast.[24,25] Bullying was assessed by whether the respondents experienced school-based or electronic bullying in the past 12 months and coded as yes/no. Eating breakfast in the past 7 days was coded as "none of the days" versus "at least some days."

A total of 17 547 surveys were completed across 2017 (n=6031), 2019 (n=5879), and 2021 (n=5637). After excluding cases with missing data, 12 892 high school students were included in the final analytic sample (see Figure 1).

Statistical Analyses

Descriptive statistics were generated, including weighted percentages and 95% confidence interval (CI). Rao-Scott's Chi-squared tests identified variables associated with mental health outcomes (ie, sadness/hopelessness, suicidality). Univariate and multivariable logistic regression models assessed the associations between mental health status and factors such as exercise and sleep, with model fit evaluated using area under the receiver operating characteristic curve (AUC). Multivariable models were adjusted for sex, race,

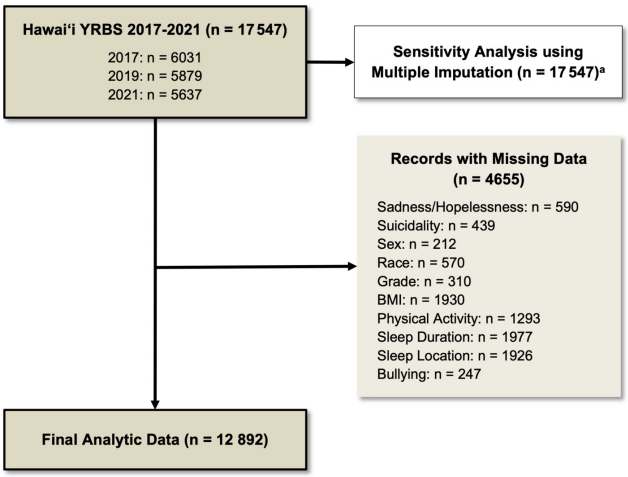

Figure 1. Flow Diagram of Study Sample Selection, Missing Data, and Sensitivity Analysis Using Multiple Imputation, Hawai'i Youth Risk Behavior Survey (YRBS), 2017-2021

[a]Sensitivity analysis was conducted using multiple imputation (20 imputed datasets) to assess the robustness of findings to missing data.

grade, BMI category, breakfast consumption, sleep duration, sleep location, physical activity, bullying, and time frame. A sensitivity analysis using multiple imputation (20 imputed datasets) was conducted to address missing data in the original 17 547 responses under the assumption of missing at random (MAR). Results were compared with complete-case analyses to assess the robustness of the findings. All analyses accounted for the YRBS sampling design. A 2-tailed *P*-value of .05 was considered statistically significant, and statistical analyses were conducted using R version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Table 1 presents the descriptive analysis. Approximately half of the adolescents were boys (50.1%), and the sample was evenly distributed across grades 9-12. About one-quarter of adolescents identified as Native Hawaiian and one-quarter as Filipino. Most adolescents had a healthy BMI (66.7%), while 28.4% were classified as overweight. Only 23.2% achieved the recommended ⩾8 hours of sleep on school nights, and 19.9% reported bullying. The data primarily consisted observations from 2017-2019 (63.4%).

Sadness/Hopelessness

Overall, 32.5% of students reported feeling sad or hopeless for at least two weeks in the past 12 months (Table 1). Grade and BMI percentile were not significantly associated with sadness/hopelessness. The prevalence of sadness/hopelessness decreased with longer sleep duration (46.3% for 0-5 hours, 30.7% for 6-7 hours, and 20.3% for ⩾8 hours on school nights) and greater physical activity (38.3% for 0-2 days, 31.5% for 3-5 days, and 26.1% for 6-7 days).

In multivariable analyses, sadness/hopelessness was significantly associated with hours of sleep, physical activity, race, sex, eating breakfast, bullying, and the COVID-19 pandemic (Table 2). Adolescents 6-7 hours or 8 or more hours of sleep on a school night had 41% and 64% lower odds, respectively, of feeling sad or hopeless compared to those getting 0-5 hours of sleep (6-7 hours: adjusted odds ratio [aOR]=0.59, 95% CI=0.52-0.67; 8+ hours: aOR=0.36, 95% CI=0.32-0.41). Adolescents physically active 6-7 days per week had lower odds of sadness/hopelessness than those active 0-2 days (aOR=0.75, 95% CI=0.65-0.87). Boys were less prone to feelings of sadness or hopelessness than girls (aOR=0.45, 95% CI=0.40-0.51). Among racial groups, other Asians were significantly less likely to report sadness or hopelessness compared to Whites (aOR=0.65, 95% CI=0.48-0.86). Furthermore, individuals who were bullied were more likely to experience sadness or hopelessness (aOR=3.33, 95% CI=2.91-3.82). After COVID-19, individuals had 27% higher odds of reporting feelings of sadness or hopelessness (aOR=1.27, 95% CI=1.11-1.46). The model fit was acceptable, with an AUC of .72 (95% CI=.71-.73).

Suicidality

Overall, 15.7% of students reported considering attempting suicide in the last 12 months (Table 1). Chi-squared tests revealed that variables race, sex, breakfast consumption, amount of sleep, sleep location, physical activity, and experience of bullying/cyberbullying were significantly associated with suicidality. Specifically, the prevalence of suicidality decreased with increasing sleep duration, from 24.2% among students sleeping 0-5 hours to 14.2% among those sleeping 6-7 hours and 8.8% among those sleeping 8 or more hours on school nights. Physical activity showed a similar trend, with prevalence declining from 19.6% among students active for 0-2 days to 14.3% for 3-5 days and 12.0% among those active for 6-7 days.

The multivariable analysis indicated that suicidality was significantly associated with physical activity, hours of sleep, sleep location, sex, race, eating breakfast, and bullying (Table 2). Adolescents who averaged 6-7 hours or 8 or more hours of sleep on a school night were also less likely to report suicidality compared with those who averaged 0-5 hours of sleep (6-7 hours: aOR=0.64, 95% CI=0.54-0.76; ⩾8 hours: aOR=0.38, 95% CI=0.31-0.46). Students without stable housing were more likely to report suicidality (aOR=1.69, 95% CI=1.29-2.21). Students who were physically active 3-5 days or 6-7 days were less likely to report suicidality compared with those active 0-2 days per week (3-5 days: aOR=0.81, 95% CI=0.67-0.97; 6-7 days: aOR=0.71, 95% CI=0.61-0.83). Boys were less likely to report suicidality than girls (aOR=0.55, 95% CI =0.46-0.65). Adolescents from certain racial groups were less likely to report suicidality than White adolescents, including Filipino (aOR=0.73, 95% CI=0.54-0.98), Other Asians (aOR=0.63, 95% CI=0.45-0.88), and Pacific Islanders (aOR=0.55, 95% CI=0.33-0.92). Those who experienced bullying were more likely to report suicidal ideation compared with those who did not report such experiences (aOR=3.48,

Table 1. Summary of Students Hawai'i High School Student Characteristics Stratified by Mental Health Status, Youth Risk Behavior Survey, 2017, 2019 and 2021

Variable	Total[a]		Sadness/Hopelessness (*Sad or feel hopeless almost every day for 2+ weeks in a row*)		Suicidality (*Seriously considered attempting suicide in the last 12 months*)	
	Unweighted n	Weighted % (95% CI)	Weighted % (95% CI)	***P* value[a]**	Weighted % (95% CI)	***P* value[a]**
All Students	12892	100	32.5 (31.4-33.8)		15.7 (14.8-16.6)	
Sex				**<.001**		**<.001**
Girl	6533	49.9 (48.4-51.4)	41.9 (40.4-43.4)		20.1 (18.7-21.7)	
Boy	6359	50.1 (48.6-51.6)	23.3 (21.5-25.1)		11.2 (10.2-12.3)	
Race/Ethnicity				**<.001**		**.001**
White	10631	16.4 (13.0-20.3)	31.7 (29.0-34.6)		17.0 (14.5-19.9)	
Filipino	2377	27.1 (25.1-29.2)	36.1 (33.9-38.4)		14.4 (12.5-16.5)	
Other Asian	883	10.5 (8.8-12.6)	23.3 (19.7-27.4)		11.3 (8.6-14.6)	
Native Hawaiian	3322	23.6 (21.1-26.4)	30.9 (28.6-33.3)		16.1 (14.3-17.9)	
Pacific Islander	533	3.6 (2.9-4.3)	29.3 (23.2-36.3)		12.1 (8.1-17.6)	
Other	4716	18.8 (18.0-19.7)	36.0 (34.0-38.0)		19.0 (17.7-20.3)	
Grade				.064		.37
9	3126	27.2 (23.8-30.9)	29.8 (27.4-32.3)		15.9 (14.5-17.4)	
10	3477	25.5 (22.8-28.5)	32.6 (30.2-35.1)		16.9 (15.0-18.9)	
11	3379	24.1 (21.5-27.0)	35.8 (33.5-38.1)		15.0 (13.1-17.2)	
12	2910	23.1 (20.8-25.6)	32.4 (28.4-36.6)		14.7 (12.7-16.8)	
Body Mass Index Percentile				.064		.27
Healthy Weight (5^{th}-85^{th})	8449	66.7 (64.9-68.5)	33.2 (31.5-35.0)		15.3 (14.3-16.4)	
Underweight (<5^{th})	540	4.8 (4.2-5.6)	35.9 (31.4-40.8)		18.7 (14.5-23.7)	
Overweight (≥85^{th})	3903	28.4 (26.9-30.0)	30.3 (28.2-32.5)		15.9 (14.4-17.5)	
How many times eat breakfast per week				**<.001**		**<.001**
0	2104	15.9 (14.8-17.1)	46.0 (42.3-49.6)		26.2 (23.9-28.5)	
1-7	10788	84.1 (82.9-85.2)	30.0 (28.7-31.4)		13.7 (12.7-14.7)	
Hours of sleep on school night				**<.001**		**<.001**
0-5	3511	27.5 (26.3-28.7)	46.3 (43.9-48.7)		24.2 (21.8-26.7)	
6-7	6298	49.3 (48.0-50.6)	30.7 (29.0-32.4)		14.2 (13.3-15.1)	
≥8	3083	23.2 (21.6-24.9)	20.3 (18.3-22.4)		8.8 (7.4-10.3)	
Usually slept in parent's or guardian's home				**.029**		**<.001**
Yes	12105	94.7 (93.8-95.4)	32.2 (30.9-33.5)		15.0 (14.2-15.9)	
No	787	5.3 (4.6-6.2)	39.1 (33.2-45.3)		27.0 (22.5-32.0)	
Physically active per week (days)				**<.001**		**<.001**
0-2	4680	37.6 (35.4-39.7)	38.3 (36.5-40.2)		19.6 (18.1-21.3)	
3-5	4393	34.5 (33.1-35.9)	31.5 (29.3-33.7)		14.3 (12.8-16.0)	
6-7	3819	28.0 (26.5-29.5)	26.1 (23.9-28.5)		12.0 (10.9-13.2)	
Bullied/E-bullied in the last 12 months				**<.001**		**<.001**
Yes	2799	19.9 (18.7-21.1)	56.2 (53.5-58.8)		33.3 (31.0-35.7)	
No	10093	80.1 (78.9-81.3)	26.7 (25.4-28.0)		11.3 (10.3-12.3)	
Time frame				**.016**		.30
2017-2019 (Before COVID)	8617	63.4 (60.2-66.5)	31.3 (30.0-32.7)		15.3 (14.1-16.6)	
2021 (After COVID)	4275	36.6 (33.5-39.8)	34.6 (32.3-37.1)		16.2 (15.1-17.3)	

Unweighted N = 12 892. CI = Confidence Interval. Weighted percentages and 95% CIs were estimated using methods accounting for the complex sampling design of the Youth Risk Behavior Survey.

[a] *P*-values were obtained using the Rao-Scott's Chi-squared test

Table 2. Associations between Mental Health Status and Student Characteristics based on Logistic Regression Analyses, Youth Risk Behavior Survey, 2017, 2019 and 2021

Variable	Sadness/Hopelessness (*Sad or feel hopeless almost every day for 2+ weeks in a row*)		Suicidality (*Seriously considered attempting suicide in the last 12 months*)	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Sex				
Girl		Reference	Reference	Reference
Boy	**0.42 (0.37-0.48)**	**0.45 (0.40-0.51)**	**0.50 (0.43-0.58)**	**0.55 (0.46-0.65)**
Race				
White	Reference	Reference	Reference	Reference
Filipino	**1.22 (1.04-1.43)**	1.15 (0.97-1.37)	0.82 (0.61-1.10)	**0.73 (0.54-0.98)**
Other Asian	**0.66 (0.52-0.84)**	**0.65 (0.48-0.86)**	**0.62 (0.44-0.88)**	**0.63 (0.45-0.88)**
Native Hawaiian	0.96 (0.83-1.11)	0.96 (0.81-1.14)	0.93 (0.77-1.14)	0.86 (0.68-1.08)
Pacific Islander	0.89 (0.65-1.24)	0.90 (0.66-1.24)	0.67 (0.42-1.08)	**0.55 (0.33-0.92)**
Other	**1.21 (1.04-1.41)**	1.11 (0.93-1.33)	1.14 (0.93-1.40)	1.01 (0.83-1.24)
Grade				
9	Reference	Reference	Reference	Reference
10	1.14 (0.98-1.33)	1.15 (0.99-1.34)	1.07 (0.90-1.28)	1.09 (0.87-1.35)
11	**1.31 (1.12-1.53)**	**1.26 (1.09-1.47)**	0.93 (0.76-1.14)	0.87 (0.72-1.06)
12	1.13 (0.89-1.43)	1.09 (0.89-1.33)	0.91 (0.73-1.12)	0.88 (0.72-1.07)
Body Mass Index Percentile				
Healthy Weight (5^{th}-85^{th})	Reference	Reference	Reference	Reference
Underweight (<5^{th})	1.13 (0.90-1.42)	1.07 (0.84-1.35)	1.27 (0.92-1.74)	1.17 (0.86-1.60)
Overweight (≥85^{th})	0.87 (0.76-1.01)	0.86 (0.73-1.02)	1.05 (0.92-1.19)	1.07 (0.93-1.23)
How many times eat breakfast per week				
0	Reference	Reference	Reference	Reference
1-7	**0.51 (0.43-0.59)**	**0.60 (0.52-0.70)**	**0.45 (0.38-0.52)**	**0.56 (0.47-0.67)**
Hours of sleep on school night				
0-5	Reference	Reference	Reference	Reference
6-7	**0.51 (0.45-0.59)**	**0.59 (0.52-0.67)**	**0.52 (0.44-0.61)**	**0.64 (0.54-0.76)**
≥8	**0.30 (0.26-0.34)**	**0.36 (0.32-0.41)**	**0.30 (0.25-0.36)**	**0.38 (0.31-0.46)**
Usually slept in parent's or guardian's home				
Yes	Reference	Reference	Reference	Reference
No	**1.35 (1.03-1.78)**	1.11 (0.85-1.44)	**2.09 (1.65-2.66)**	**1.69 (1.29-2.21)**
Physically active per week (days)				
0-2	Reference	Reference	Reference	Reference
3-5	**0.74 (0.65-0.84)**	0.89 (0.77-1.02)	**0.68 (0.58-0.81)**	**0.81 (0.67-0.97)**
6-7	**0.57 (0.50-0.65)**	**0.75 (0.65-0.87)**	**0.56 (0.49-0.64)**	**0.71 (0.61-0.83)**
Bullied/E-bullied in the last 12 months				
Yes	**3.52 (3.10-4.01)**	**3.33 (2.91-3.82)**	**3.93 (3.38-4.58)**	**3.48 (3.01-4.04)**
No	Reference	Reference	Reference	Reference
Time frame				
2017-2019 (Before COVID)	Reference	Reference	Reference	Reference
2021 (After COVID)	**1.16 (1.03-1.31)**	**1.27 (1.11-1.46)**	1.07 (0.94-1.21)	1.15 (0.99-1.34)

OR = Crude Odds Ratio. CI = Confidence Interval. aOR = Adjusted Odds Ratio. ORs (aORs) and 95% CIs were estimated using logistic regression models accounting for the complex sampling design of the Youth Risk Behavior Survey. All covariates included in the adjusted analyses are shown in the aOR column.

95% CI=3.01-4.04). Model discrimination was acceptable (AUC=.72, 95% CI=.71-.74).

To address the impact of missingness, a sensitivity analysis using multiple imputation was conducted (Table 3). Results were consistent with those from the complete-case multivariable analysis in terms of both magnitude and statistical significance. Differences in ORs between the multiple imputation and complete-case analyses were generally small (maximum absolute difference ⩽0.31), indicating consistent results across methods.

Table 3. Multivariable Logistic Regression Results Based on Five Imputed Datasets Using Multiple Imputation, Youth Risk Behavior Survey, 2017, 2019 and 2021

Variable	**Sadness/Hopelessness (*Sad or feel hopeless almost every day for 2+ weeks in a row*)**	**Suicidality (*Seriously considered attempting suicide in the last 12 months*)**
	aOR (95% CI)	**aOR (95% CI)**
Sex		
Girl	Reference	Reference
Boy	**0.48 (0.43-0.54)**	**0.60 (0.52-0.68)**
Race		
White	Reference	Reference
Filipino	1.29 (1.00-1.44)	**0.73 (0.55-0.98)**
Other Asian	**0.66 (0.50-0.87)**	**0.59 (0.42-0.82)**
Native Hawaiian	1.00 (0.86-1.16)	0.87 (0.71-1.07)
Pacific Islander	0.98 (0.68-1.41)	**0.57 (0.34-0.94)**
Other	1.14 (0.96-1.34)	0.97 (0.81-1.18)
Grade		
9	Reference	Reference
10	1.19 (1.00-1.42)	1.11 (0.91-1.36)
11	**1.26 (1.10-1.45)**	0.92 (0.75-1.12)
12	1.09 (0.90-1.32)	0.85 (0.70-1.04)
Body Mass Index Percentile		
Healthy Weight (5^{th}-85^{th})	Reference	Reference
Underweight (<5^{th})	1.04 (0.82-1.32)	1.18 (0.84-1.67)
Overweight (≥85^{th})	0.88 (0.76-1.03)	1.08 (0.92-1.26)
How many times eat breakfast per week		
0	Reference	Reference
1-7	**0.61 (0.52-0.71)**	**0.56 (0.48-0.66)**
Hours of sleep on school night		
0-5	Reference	Reference
6-7	**0.62 (0.55-0.71)**	**0.67 (0.57-0.79)**
≥8	**0.39 (0.35-0.44)**	**0.42 (0.34-0.52)**
Usually slept in parent's or guardian's home		
Yes	Reference	Reference
No	**1.28 (1.02-1.61)**	**2.00 (1.59-2.52)**
Physically active per week (days)		
0-2	Reference	Reference
3-5	0.90 (0.79-1.02)	**0.83 (0.71-0.97)**
6-7	**0.78 (0.68-0.90)**	**0.70 (0.60-0.80)**
Bullied/E-bullied in the last 12 months		
Yes	**3.38 (2.97-3.85)**	**3.51 (3.09-3.99)**
No	Reference	Reference
Time frame		
2017-2019 (Before COVID)	Reference	Reference
2021 (After COVID)	**1.28 (1.12-1.46)**	1.14 (0.99-1.32)

aOR = Adjusted Odds Ratio. CI = Confidence Interval.
Sensitivity analysis using multiple imputation (20 imputed datasets). aORs and 95% CIs were estimated using multivariable logistic regression models accounting for the complex sampling design of the Youth Risk Behavior Survey. All covariates included in the adjusted analyses are shown in the aOR column.

Discussion

This study examined the association between mental health, sleep, physical activity, and the COVID-19 pandemic among adolescents in Hawai‘i. Furthermore, factors such as subjection to bullying, as well as demographic variables, were considered.

Findings revealed that sleep during significantly impacts suicidality and depressive symptoms. Students sleeping 0-5 hours reported higher rates of sadness/hopelessness and suicidal thoughts than those sleeping 6 or more hours. While these findings highlight sleep duration as a key risk factor, the study did not assess sleep quality, which is a limitation. Prior research indicates that sleep quality may be a significant predictor of psychological distress than duration alone.[26,27] Meta-analyses and longitudinal studies indicate that poor sleep quality and insomnia symptoms are more strongly associated with mental health and suicidality.[28-30] Future research should incorporate multidimensional sleep assessments to capture both duration and quality.

While location of sleep is significantly associated with suicidality, it does not appear to affect feelings of sadness/hopelessness. This association likely reflects broader risk factors such as housing instability or family disruption, rather than sleep context alone. Adolescents experiencing unstable housing or family homelessness are at higher risk for suicidal ideation and attempts.[31,32] Sleep location in this study may therefore serve as a marker of acute environmental stressors, highlighting the need for future research to include direct measures of housing stability and family context.

Consistent with previous studies,[10,12,33,34] this study also demonstrated the importance of physical activity in maintaining adolescent mental health. Although the magnitude of its association was attenuated after adjusting for other covariates, physical activity remained a significant and meaningful factor. This suggests that engagement in regular physical activity may exert both direct and indirect effects on psychological well-being, potentially through mechanisms such as stress reduction, improved sleep quality, enhanced self-esteem, and increased social interaction. This underscores its continued relevance as a target for prevention and health promotion efforts.

Racial disparities in mental health were observed in this study, supporting prior research finding.[35] Compared with White youth, other Asian youth had lower odds of both suicidality and sadness/hopelessness and Filipino and Pacific Islander youth had lower odds of suicidality. Although national data often indicate elevated risk for depressive symptoms and suicidality among certain minority groups,[36] these findings may reflect unique protective factors in Hawai‘i. Prior research suggests that Asian and Pacific Islander youth benefit from strong family support, cultural connectedness, and community cohesion, which are associated with greater resilience and psychological well-being.[22,37] Connections to family, community, and cultural practices have also been linked to lower perceived stress and reduced suicidal risk among Asian and Pacific Islander youth more broadly.[22,37] In addition, these patterns may reflect differences in psychosocial risk and protective factors between non-White versus White youth. The collectivistic nature in communities of color could serve may offer protection adverse mental health consequences, particularly internalizing disorders such as depression and suicidality. In contrast, the individualistic nature prevalent in Western culture and more commonly endorsed by White youth may increase vulnerability to social isolation and related internalizing symptoms.

This study has several limitations. First, it is unclear whether some independent variables, such as physical activity and sleep, were unaffected by mental health outcomes. Individuals with depression may neglect physical well-being, raising concerns about reverse causation and suggesting a potential bidirectional relationship between mental health and health behaviors, whereby poor mental health adversely affects health behaviors, while disrupted sleep and reduced physical activity may in turn exacerbate psychological distress. Clarifying these dynamics would require longitudinal data. Second, suicidal ideation was selected rather than suicide plans or attempts, because suicidal ideation represents an earlier stage along the suicidal continuum, is a critical target for prevention and early intervention efforts, and is more commonly and reliably reported in survey-based data. Future studies are encouraged to examine these associations across multiple stages of suicidal behavior. Third, this study did not account for all variables potentially linked with mental health. Specifically, screen-use metrics such as time spent TV or gaming were excluded to prevent issues with confounding and multicollinearity. Further research should investigate these factors alongside socioeconomic background and parental data to better understand their collective impact on health risk and sleep patterns.[38] Fourth, the YRBS measures overall physical activity, failing to distinguish between moderate and vigorous intensities. This is a notable limitation, as the neurological and mental health benefits of exercise often follow a dose-response relationship tied specifically to intensity levels.[39,40] Future studies should investigate distinct modalities such as strength training, cardiovascular exercise, competitive sports while exploring barriers to participation to better understand their unique impacts on mental health.[41] Fifth, certain racial categories were collapsed to ensure statistical robustness; however, this have obscured specific trends. Future research should utilize more disaggregated data to provide a more nuanced analysis of these demographics. Sixth, a substantial proportion of missing data was present in the dataset. Although multiple imputation was used under the assumption that data were MAR, the possibility of non-random missingness cannot be excluded. Therefore, residual bias may still be present if the missingness mechanism deviated from the MAR assumption. Furthermore, due to the nature of the YRBS survey procedures, the accuracy of the self-reported data may introduce bias. Although the sample size was relatively large, the inclusion of only public schools in the Hawai‘i YRBS dataset could introduce selection bias.

Despite these limitations, this study has several notable strengths. To the authors' knowledge, it is the first to ex-

amine the association between Hawai'i adolescents' mental health status and both sleep and physical activity while adjusting for multiple covariates. By combining Hawai'i State High School YRBS data from 3 survey years, a relatively large and representative sample of adolescents in Hawai'i was analyzed. This approach also allowed for the inclusion of more diverse and detailed racial groups than would not have been possible using the national YRBS dataset. The findings highlight important opportunities for intervention: to better support student mental health, high school administrations and teachers should emphasize the importance of adequate sleep and remain attentive to chronic sleep deprivation and drowsiness among students.[42] Furthermore, public health policies should more widely consider racial- and sex-tailored mental health prevention strategies, especially for adolescents.

Conclusion

Adequate sleep and physical activity are crucial for adolescents' mental health and should be central to public health promotion. The racial differences observed in this study underscore the unique mental health challenges faced by adolescents in Hawai'i. Future interventions should address these inequities through targeted, culturally responsive prevention and support strategies that reflect the state's diverse demographic profile.

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Conflicts of interest

No authors have conflicts of interest to report; nor competing financial interests.

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The Climate Change and Health Working Group: Breaking Down Silos to Advance Health and Resiliency in Hawai'i

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Abstract

The Spotlight on Nursing is a recurring column from the University of Hawai'i at Mānoa School of Nursing and Dental Hygiene (SONDH). It is edited by Holly B. Fontenot, PhD, APRN, WHNP-BC, FAAN, FNAP; Associate Dean for Research, Professor, and Frances A. Matsuda Chair in Women's Health for SONDH, and HJH&SW Contributing Editor; and Joanne R. Loos PhD, Science Writer for SONDH.

Hawai'i is experiencing the effects of climate change, including increased temperatures, decreased rainfall, and higher frequency of extreme weather. In 2023, the Climate Change and Health Working Group (CCHWG) was formed, bringing together over 250 public health professionals dedicated to catalyzing community action by adopting a health-oriented approach to challenges posed by climate change. To date, members have engaged in crafting public policy initiatives to embed health perspectives into statewide legislation on climate change issues and created community listening sessions aimed at matching resources to the needs of underserved communities. The CCHWG's actions are charting a roadmap to guide collaborative efforts between health professionals and communities aimed at mitigating the health impacts of climate change and bolstering resilience. Future goals include expanding efforts across the state and to other populations across the Pacific to implement similar community-driven transformative change.

Acronyms

AMA: American Medical Association
ANA: American Nurses Association (ANA)
APHA: American Public Health Association
CCHWG: Climate Change and Health Working Group
DOH: Hawai'i State Department of Health

Introduction

Hawai'i is witnessing the effects of climate change, including higher temperatures, rising sea levels, and more frequent extreme weather. Since 1950, the average temperatures in Hawai'i have risen 2 degrees Fahrenheit, and coastal seas are 10 inches higher in some parts of the state.[1,2] Overall rainfall in the state is decreasing, yet tropical cyclone intensity is predicted to increase, along with heavier rains and increased flooding.[3-6] The northeast trade winds that normally cool the islands have been decreasing for decades and are projected to decline further.[7] These effects substantially increase the risks to human health, exposing Hawai'i residents to more extreme heat, more intense hurricanes, and higher risks of wildfires, water-borne infections, and food insecurity.[8-11] The health impacts of climate change are illustrated in a "pinwheel" resource from the Hawai'i State Department of Health (DOH) [**Figure 1**]. Rising temperatures from greenhouse gases for example, contribute to extreme heat, which can lead to heat-related illness, dehydration, occupational hazards, and worsening of cardiovascular and lung disease.[12-15] Further, all of these changes can contribute to worsening mental health, including depression and anxiety.[16] The 2023 Maui wildfires, which killed more than 100 people, were fueled in part by climate driven temperature increases and prolonged drought,[17,18] and resulted in lasting health problems among survivors, including respiratory, cardiovascular, and mental health issues.[19]

Health care professionals must work with their communities and patients to mitigate risks and exposures related to the changing climate. The Climate Change and Health Working Group (CCHWG) is a cadre of health professionals dedicated to community-driven climate action in the State of Hawai'i. This paper, authored by members of the CCHWG, will describe how the group is working collaboratively to protect the health of Hawai'i residents in the face of the changing climate with the aim of making the CCHWG a model for climate and health advocacy that other communities, states, and organizations may learn from and replicate.

Breaking Down Climate Change and Health Silos

Nationally, organizations like the American Medical Association (AMA), the American Public Health Association (APHA), and the American Nurses Association (ANA) recognize the public health threat from climate change and support policies and actions to both mitigate and adapt to these threats.[20-22] In Hawai'i, the CCHWG was formed in 2023 to specifically highlight the impact of climate change on health.[8] Initiated by volunteers from the Hawai'i State Department of Health (DOH) and the University of Hawai'i John A. Burns School of Medicine, the group has grown to

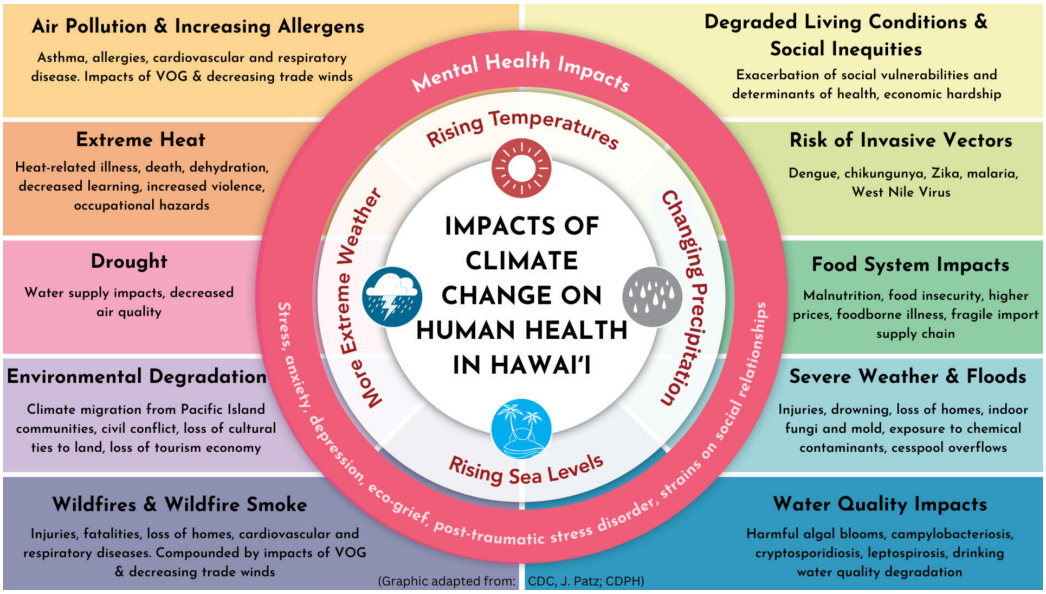

Figure 1. Impacts of Climate Change on Human Health in Hawai'i; Adapted from Centers for Disease Control (CDC) and the California Department of Public Health (CDPH)

involve more than 250 public health professionals. Current members include physicians, nurses, social workers, public health professionals, environmental policy experts, nonprofit professionals, undergraduate and graduate students, local elected officials, and state-funded climate change organizations. At the time of its founding, discussions surrounding climate change in Hawai'i were highly focused on environmental protection or infrastructure projects. Few efforts focused on health impacts of climate change, and those that did were siloed and disconnected. Establishment of the CCHWG filled gap by gathering health professionals to approach climate change through a health lens and aligning shared goals and community action. United by the values of equity, justice, and *Aloha*, CCHWG members collaborate across disciplines and communities to strengthen public health resiliency in Hawai'i in response to our changing climate. Using a data-driven approach, the organization's mission is to research and communicate the human health impacts of climate change and to advocate for policy solutions that prioritize the most at-risk community members in Hawai'i.[8] These goals are accomplished through monthly meetings and activities clustered around policy initiatives, community listening sessions, and climate health education.

Advocating for Climate Change and Health Policy

A major priority of the CCHWG is to influence public policy in ways that highlight health impacts associated with climate change. Testimony for climate-change-related legislation frequently lacks perspectives from health professionals. For example, legislation proposed to address cesspool infrastructure solutions in Hawai'i has historically garnered testimony from landowners, the State Department of Transportation, and environmental groups, but lacked testimony detailing the impact that cesspools can have on health. This is problematic, as the state's 83000 existing sewage cesspools discharge untreated wastewater and pathogens, putting residents at risk for gastroenteritis, conjunctivitis, diarrhea, and skin infections.[23-27]

Recognizing the need to improve Hawai'i health professionals' understanding of the legislative process, the CCHWG provided training and guidance to its members to improve public policy advocacy. Activities included educating members on Hawai'i's overall legislative process, effective interaction with state legislators and county officials, and climate-linked public policies. The CCHWG created a rubric to help members evaluate and prioritize legislative initiatives for impact on climate change and health, while also considering issues such as the most appropriate leading voice, whether the bill solved a problem, or the likelihood of a bill to pass [**Figure 2].** Student members conducted historical evaluations to provide perspective of how various bills fit into the "pinwheel" of health effects, provided a preview of what bills to possibly expect, gathered the latest evidence for testimony, and created an organizing framework to track legislation. CCHWG members met weekly to track legislation, coordinate testimony, prepare scientific summaries on health and climate change, draft written testimony, and prepare oral testimony in person and via videoconference. In several instances, CCHWG testimony helped amplify community voices. For example, concerns about heat-related illness raised during listening sessions in drought-prone communities led the CCHWG to prioritize the issue, ultimately resulting in a policy proposal submitted to the legislature. Additionally, student CCHWG volunteers drafted original resolutions relating to climate and health which were introduced to legislators. One of these resolutions, Senate Concurrent Resolution 111, became formally adopted in the 2025 session.[28] This resolution declared climate change a public health emergency –

Figure 2. Policy Guide, Climate Change and Health Working Group 2024

the first such declaration for any state – and urged Hawai'i law makers and state agencies to assess climate impacts on health and collaborate across sectors to strengthen the public health response to the climate crisis.

Listening to the Community

Another key initiative of the CCHWG is to collect community input to understand how climate change impacts health in Hawai'i and to identify the resources needed to support communities facing greater health disparities. Evidence shows that nurses and doctors are viewed as trusted messengers to deliver climate change information.[29] Thus, the CCHWG initiated a series of listening sessions to hear first hand about the perceived health impacts that climate change is having on Hawai'i communities. The goals of the listening sessions were to build trust, identify community expertise, and provide opportunities for community members to be heard.[30,31] Listening sessions were supported in part by Kaiser Health Systems, which allowed CCHWG to provide community participants with food and renumeration for their time.

The first 2 listening sessions occurred in West O'ahu, an area at risk of drought, wildfires, and infrastructure issues, that is also home to communities with high concentrations of Native Hawaiian individuals and families. Nurses and Native Hawaiian health professionals from the CCHWG provided community attendees with information

regarding climate change and health effects. Participants then shared their own experiences with climate change and health. Community listening sessions revealed climate-related health concerns that might otherwise have remained unnoticed, such as increases in respiratory conditions during wildfire season, worries about heat-related illness in the elderly, or stress related to food insecurity after storms. These sessions not only guided the CCHWG's advocacy priorities at the state legislature but also helped build trust with underrepresented communities. By offering a space for residents to share their experiences and connect with local health and climate leaders, the CCHWG laid the groundwork for more inclusive and community-responsive interventions.

The listening sessions also helped the CCHWG identify gaps in community education, outreach, or action, which the group could then help to fill by leveraging Hawai'i's health network to engage communities and specifically address identified concerns. For example, in response to concerns about heat-related illness among the elderly, the CCHWG partnered with a local senior group on a grant to train members in heat safety, empowering them to support others in their own communities. Future plans include conducting further community educational outreach such as staffing health fairs, making and disseminating health educational materials, creating wider partnerships with communities and health organizations, and involving health professional students, including nursing and public health students, in these efforts.

Strengths and Challenges

The CCHWG has demonstrated how a volunteer-based, interprofessional network can promote health-centered climate action. Through monthly meetings, subgroup formation, and shared leadership, the CCHWG has created a collaborative space where members can initiate and conduct projects responsive to local needs. Thus far, a major accomplishment of the CCHWG has been the breaking down of silos between sectors and disciplines. By introducing a health-focused framework, the CCHWG has successfully brought new voices, particularly from the clinical and public health communities, into the climate conversation. This has led to more comprehensive health-focused testimony at the legislative level, the development of tailored messaging around climate change health impacts, and the integration of lived community experiences into advocacy and education. In this way, the CCHWG has exemplified the missions of national groups, such as the AMA, APHA, and ANA in supporting actions to educate, mitigate, and adapt to climate related health issues.

A major strength of the CCHWG is its conversational approach, which allows ideas to emerge organically. The group's large network of professionals is united by a shared vision for health in a changing climate. Partnerships initiated among CCHWG members have also fostered cross disciplinary collaboration. For example, the group has linked a statewide food gardening initiative with nurses to educate outdoor workers about the risk of heat-related illnesses. The group also benefits from a structure that allows members to form subgroups that are responsive to the members' interests and the group's capacity. For example, CCHWG was able to pivot its efforts to address growing awareness of climate-related anxiety and trauma among people impacted by the 2023 Maui Wildfires.

Several challenges remain. As a volunteer-led group, the CCHWG faces limitations in time, funding, and capacity. Much of its work relies on the goodwill and energy of a small group of organizers, students, and busy professionals. Institutional support remains inconsistent, and climate-health partnerships must compete with other pressing public health issues for attention and resources. Furthermore, although listening sessions have been a promising engagement tool, scaling these efforts equitably across islands and communities will require greater coordination and sustained funding through grants.

The Road Ahead

The CCHWG illustrates how health professionals can take a central role in climate adaptation and mitigation, not only through clinical practice but through community engagement, policy advocacy, education, and partnership building. Its flexible, inclusive, and data-informed approach may serve as a replicable model for other communities, states or regions seeking to integrate health more fully into climate action. Despite challenges, the CCHWG's first 2 years of work offers valuable lessons for others seeking to link health and climate action. Trusted messengers, especially health care professionals such as nurses and physicians, can play a pivotal role in shifting public and political will. Embedding community stories and lived experiences into policy advocacy enhances both its relevance and legitimacy.

Looking ahead, the CCHWG aims to strengthen its efforts by formalizing partnerships with community health centers, expanding educational outreach, and disseminating findings from its listening sessions to guide evidence-based policy. The CCHWG is also exploring how its model might support climate-resilient health advocacy in Pacific Island nations, many of which bear a disproportionate climate burden despite contributing minimally to global emissions. By sharing lessons learned, organizational structures, and educational resources, the CCHWG hopes to model how health professionals and communities can align efforts to mitigate impacts and bolster resilience to climate change.

*The Hawai'i Public Health Institute (HIPHI) is the fiscal sponsor for the CCHWG

**The opinions expressed in this document are those of the authors and do not reflect the official position of the State of Hawai'i Department of Health.

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Hawai‘i Journal of Health & Social Welfare (HJH&SW) Style Guide for the Use of Native Hawaiian Words and Diacritical Markings

The HJH&SW encourages authors to use the appropriate diacritical markings (the ‘okina and the kahakō) for all Hawaiian words. We recommend verifying words with the Hawaiian Language Dictionary (http://www.wehewehe.org/) or with the University of Hawai‘i Hawaiian Language Online (http://www.hawaii.edu/site/info/diacritics.php).

Authors should also note that Hawaiian refers to people of Native Hawaiian descent. People who live in Hawai‘i are referred to as Hawai‘i residents.

Hawaiian words that are not proper nouns (such as keiki and kūpuna) should be written in italics throughout the manuscript, and a definition should be provided in parentheses the first time the word is used in the manuscript.

Examples of Hawaiian words that may appear in the HJH&SW:

‘āina	**Māori**	**O‘ahu**
Hawai‘i	**Lāna‘i**	**‘ohana**
kūpuna	**Mānoa**	**Wai‘anae**