Developing a Predictive Model for Measuring Health Literacy in Hawai'i's Adult Populations

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ABSTRACT

Background: Adequate health literacy is necessary to effectively participate in one's own health care, yet many American adults lack the health literacy skills to navigate the US health care system. Lower health literacy has been associated with poorer health status, higher health care utilization, and greater health disparities in studies conducted both nationally and in Hawai'i. Other factors associated with inadequate health literacy include older age, immigrant status, ethnic minority status, poverty and fewer years of education. Successful health interventions aimed at reducing disparities and improving health outcomes should be based on adequately identifying the unique characteristics of the population, including health literacy skills. Direct measurement of health literacy is labor intensive and controversial, hindering its study in population-based research. National health literacy predictive models have been developed to help address this problem. To date, the applicability of national health literacy predictive models in Hawai'i's ethnically diverse population has not been studied.

Objective: To identify demographic variables associated with low health literacy and develop a multivariable predictive model for low health literacy in Hawai'i's adult population.

Methods: We completed a cross-sectional analysis of a representative sample of Hawai'i's adult population from the annual telephone based Hawai'i Health Survey (HHS) data, years 2008 and 2010. The sample included 11,941 respondents. Descriptive analysis was used to identify individual socio-demographic variables associated with low health literacy. Predictors included age, gender, marital status, educational attainment, race/ethnicity, insurance status, poverty status, rural residence and migration status. We used multivariable logistic regression models,

including sub-group analysis for age over 65 years and migration status, to predict the probability of inadequate health literacy.

Results: In the descriptive results, 18% had low health literacy, which was significantly associated with extremes of age (<25 or >84 years old, compared to those ages 25-64 and 64-84 years old), less than high school education (compared to high school graduates or post high school education), non-white ethnicity, being poor, lack of health insurance, rural residence, and being born outside the U.S. ($p<0.01$). In the multivariable logistic regression model with the full population, Chinese, Filipinos, Japanese and Pacific Islanders were significantly more likely to have low health literacy compared to whites, even after control for the socio-demographic factors of education, poverty, insurance and rural residence. In the models including migration status, controlling for socio-demographic factors, low health literacy was associated with non-U.S. born, rural residence, lacking health insurance and Hawaiian, Chinese, Filipino, Japanese and "Other" ethnicities ($p<0.05$). Within the age 65+ year models, only age 85+ years and Pacific Islander ethnicity had increased odds for low health literacy ($p<0.05$). Across all models, those with less than high school education had twice the odds of having lower health literacy compared to those who completed high school or post-secondary education ($p<0.02$). Predictive accuracy for all models achieved AUROC between 0.624-0.689.

Conclusions: Several of Hawai'i's Asian American and Pacific Islander ethnic groups have significantly lower health literacy compared to White residents. Based on comparison of Hawai'i and national models' statistical results, this study found a lack of predictive accuracy for Hawai'i health literacy models, patterned after national models, when applied to Hawai'is' adult

population. A locally derived multivariable model may lead to better detection of community specific information than using individual predictors of low health literacy, and could supply Hawai'i's healthcare stakeholders with an additional tool to help focus health interventions.

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BACKGROUND

The expectation for patients' direct involvement in managing their own health has expanded over the last several decades with "patient centered care" and "shared decision making" models now at the forefront of health policy, health care systems and direct clinical interactions (IOM, 2001, p. 28; Epstein, Fishcella & Strange, 2010). The individual's health related responsibilities have been further magnified with the advent of the Affordable Care Act (2010) and increased number of Consumer Driven Health Plans (CDHP), requiring selection of health insurance coverage and management of health care dollars based on a complex assessment of one's health care needs. Additionally, health promotion efforts at the community level depend on individuals' health related awareness and support of programs designed to improve living conditions and support healthy lifestyles.

To achieve optimal health, adequate health literacy, defined as "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (Nielsen-Bohlman, Panzer, & Kindig, 2004, p. 32), is needed to successfully navigate our multi-layered health care system. To meet the larger construct of public health, some experts propose that a broader concept of health

literacy is critical to understand the factors influencing one's own health and empowering patients to use health information in ways that promote and maintain good health at both personal and community levels (Nutbeam, 2000a; Nutbeam, 2000b; McQueen et al.,2007).

At the federal level, the U.S. Department of Education's 1992 National Assessment Literacy Survey (NALS) was commissioned in part to identify how many individuals had ''below basic skills'' and needed to improve their health literacy with basic adult education (Kirsch, 1993). At the request of the U.S. Department of Health and Human Services (Healthy People, 2010) and health care researchers, health literacy items were included the 2003 National Assessment of Adult Literacy survey (NAALs) to identify persons with *proficient, intermediate, basic and below basic* health literacy skills. The NAALs became the first population based literacy assessment to directly measure health literacy in U.S. adults (Kutner, Jin, & Paulsen, 2006). Results of the study produced national estimates of adult health literacy which suggest that 9 out of 10 American adults experience difficulty understanding common health information, and that over one-third of Americans are functioning at the lowest level of health literacy (Kutner et al., 2006; Neilsen-Bohman, et al., 2004, p. 61).

The impact of low health literacy in the U.S. has been associated with many aspects of health, including lower use of preventive services, lower rates of health insurance, presentation at later stages of disease, higher health care costs, increased use of emergency services and hospitalizations, and higher mortality (Bennet et al., 1998; Gazmararian et al., 1999; Howard, Gazmararian, & Parker, 2005; Howard , Sentell & Gazmararian, 2006; Sudore et al.,2006a; Sudore et al., 2006b:Wolf, Davis, Tilson, Bass, & Parker, 2006; Baker et al., 2007; Cho, Lee,

Arozullah, & Crittenden, 2008; Murray, Tu, Wu, Morrow, Smith, & Brater, 2009; Bennett, Chen, Soroui, & White, 2009; Berkman, Sheridan, Donahue, Halpern, & Crotty, 2011; Rasu, Bawa, Suminski, Snella, & Warady, 2015; Vernon, Rosenbaum, & DeBuono, 2007). Studies indicate those with low health literacy are challenged by the management of chronic illness, which requires a complex set of skills including the ability to self -monitor and strategize how to proactively treat conditions such as diabetes, asthma, HIV, congestive heart failure (Paasche-Orlow, Parker, Gazmararian, Neilsen-Bohlman, & Rudd, 2005; Kripalani, Henderson, Chui, Robertson, Kolm, & Jacobson, 2006; Davis & Wolf, 2006; Reahl, Bond, Woods, Patry, & Sleeper, 2006; Waldrop-Valverde, Jones, Jayaweera, Gonzales, Romero, & Ownby, 2009: Waldrop-Valverde, Jones, Gould, Kumar, & Ownby, 2010). Inadequate health literacy can be financially costly as it is associated with misunderstandings about care recommendations, potentially leading to poorer adherence and health outcomes (Gazmararian, Kripalani, Miller, Echt, Ren, & Rask, 2006). Persons who read at lower grade levels are up to three times more likely to suffer an adverse health outcome (Howard, Gazmararian, & Parker, 2005; DeWalt, Berkman, Sheridan, Lohr, & Pignone, 2004). In one large population study, lower literacy equated with increased odds of having a condition which prevented the person being employed (Sentell & Halpin, 2006).

While limited health literacy may affect all persons, the NAALs and other population based studies have revealed a disproportionate number of people with low literacy for groups that are older, people with low economic status and educational attainment, certain ethnic groups and immigrants (Kutner et al., 2006; Gazmararian et al., 1999; Cho et al., 2008; Baker, Parker,

Williams, Clark, & Nurss, 1997; Davis, et al., 1991; Hanchate, Ash, Gazmararian, Wolf, Paasche-Orlow, 2008; Paasche-Orlow et al., 2005). For the largest consumers of health care, persons aged 65 years and older, 66% were found to operate at *basic* or *below basic* level of health literacy. Nearly half of the persons living at the federal poverty limit (FPL) or near poverty status (up to 200% FPL) scored in the *basic* range for health literacy (Kutner et al., 2006; Martin et al., 2009). Hispanics and Blacks had the highest rates of *below basic* and *basic* health literacy skills compared with Whites in the NAALs study, a consistent finding among other population studies (Kutner et al., 2006; Martin et al., 2009; Miller, Degenholtz, Gazmararian, Lin, Ricci, & Sereika, 2007; Hanchate et al., 2008). Immigrant populations (Latino and Asian) and those with limited English proficiency (LEP) or those who were non-English speaking before entering U.S. schools are more likely to have reported low health literacy (Kutner et al., 2006; Sudore, Landefeld, Pérez-Stable, Bibbins-Domingo, Williams, & Schillinger, 2009; Martin et al., 2009; Sentell & Braun, 2012).

Finally, half of the adults who had never completed or attended high school or equivalency scored in the *below basic* health literacy range compared with only 15% who had completed high school (Kutner et al., 2006; Howard et al., 2006; Martin et al., 2009). Several of these groups received attention in the AHRQ National Healthcare Quality and Disparities Report 2007, with evidence that lower literate Americans receive less optimal health care. Subsequent reports from AHRQ continue to demonstrate that health care quality and access are suboptimal, especially for ethnic minority and low-income groups (AHRQ, 2007, p. 9; AHRQ, 2008-2013; Sentell & Halpin, 2006; DeRose, Escarce, & Lurie, 2007).

Studies in Hawai'i, with its wide ethnic diversity and growing immigrant population have documented population health disparities and poorer health outcomes in sub segments of Hawai'i's population (Busch, Easa, Grandinetti, Mor, & Harrigan, 2003; Park, Braun, Horiuchi, Tottori, & Onaka, 2009; Mau, Sinclair, Saito, Baumhofer, & Kaholokula 2009; Kaholokula, 2008; Heo, Sentell, Li, Ahn, Miyamura, & Braun, 2014; Sentell, Tsoh, Davis, Davis, & Braun, 2015). Several disaggregated investigations provide the health status of specific Asian American, Hawaiian and Other Pacific Islander populations, citing increased complications related to diabetes, strokes, congestive heart failure and hospitalizations (Sentell, Baker, Onaka, & Braun, 2011; Sentell et al., 2013; Heo et al., 2015). While the impact of lower health literacy has not been directly studied in Hawai'i's population, two recent investigations provide health literacy levels for several racial and ethnic groups relative to their health conditions, including diabetes, depression, self -perceived health status and obesity (Sentell, Baker, Onaka, & Braun, 2011; Sentell et al., 2013; Lassetter et al., 2015). The differences in sociodemographic and cultural determinants of health and outcomes, highlighted in studies of Hawai'i's highly varied racial and ethnic communities, have emphasized the need for more focused study and interventions (Pourat, Kagawa-Singer, Breen, & Sripipatana, 2010; Ghosh, 2010; King, McNeely, Thorpe, Mau, Lo, Liu, & Chow, 2012; Sentell, Juarez, Ahn, Tseng, Chen, Salvail, & Mau, 2014; Davis, Tam, & Taira, 2016; Nakagawa, Ahn, Taira, Miyamura, & Sentell, 2016; Braun, Yang, Onaka, & Horiuchi, 1997).

Ongoing efforts by public and private health care sponsors and researchers to improve quality, reduce disparities and address growing costs, cannot ignore the relevance of low health

literacy within the health paradigm for individuals and communities (Nielson-Bohlman et al., 2004, p. 2; Paasche-Orlow & Wolf, 2010). The development of methods to measure or estimate health literacy skills at the local level is critical to identify the contribution of health literacy on health and outcomes for both communities and individuals (U.S. Department of Health and Human Services, 2010, p. 43). These assessments may provide important information for developing appropriate health programs and services for specific population needs (U.S. Department of Health and Human Services, 2010, p. 45; Pleasant, 2014, Guyz, Kenny, Dickson-Swift, & Threlkeld, 2015).

Current measurement methods of health literacy follow one of three approaches: direct testing of an individual's abilities, self-report of abilities, and demographic based proxy measures (Jordan, Osborne, & Buchbinder, 2011). Early direct measurement tools were based on concepts from standardized literacy tests, encompassing reading comprehension and numeracy. Two tests, mainly used in research settings, have provided the standard by which other measurements of health literacy are compared for construct validity. The Test of Functional Health Literacy for Adults (TOFHLA) was constructed to test for functional health literacy assessing numeracy, reading and writing skills using hospital or health-related materials (Parker, Baker, Williams, & Nurss, 1995). The Rapid Estimate of Adult Literacy Measure (REALM) assesses for correct pronunciation of 125 commonly used medical words found in patient education materials (Davis et al., 1991). Reported limitations of all direct testing instruments include time for completion, participant cooperation, and English-language orientation of tools (Davis, Michielutte, Askov, Williams, & Weiss, 1998).

To expedite health literacy testing suitable for use in clinical settings, researchers formulated self- reported health literacy measurements [i.e., Set of Brief Screening Questions (SBSQ) and Single Item Literacy Scale (SILS)]. Participants are asked to rate their perceived ability to understand health-related materials (Williams et al., 1995; Chew, Bradley, & Boyko, 2004; Wallace, Rogers, Roskos, Holiday, & Weiss, 2006) or to collect, communicate, and evaluate health information (Ishikawa &Yano, 2008). These or similar questions have been used to estimate health literacy in large population-based surveys, including the California Health Interview Survey 2007 (CHIS, 2011) and the Health Literacy Survey European Union 2009-2012 (Sorensen et al., 2015). Drawbacks of self-reported data are social stigmatization, where a respondent may not want to report undesirable behavior (Parikh, Parker, Nurss, Baker, & Williams, 1996) and the risk of assessing self-efficacy or behavior instead of health literacy (Ishikawa & Yano, 2008).

Direct testing of health literacy is time consuming, (Davis et al., 1998; Martin et al., 2009: Miller et al., 2007) and self-reported methods of assessment have not been routinely incorporated in large national population-based research (National Health and Nutrition Examination Survey, NHANES; National Health Information Survey, NHIS; Behavior Risk Factor Surveillance System, BRFSS) or in Hawai'i's major health studies (Kuakini Honolulu Heart Program and Honolulu-Asia Aging Study; Hawai'i BRFSS), which preclude study of association of health literacy with markers of many health behaviors and disease states (Hanchate et al., 2008).

A third approach to estimate health literacy has been to construct validated predictive models using commonly available demographic characteristics (Miller et al., 2007; Hanchate et al., 2008; Martin et al., 2009). Two of the models (Miller et al., 2007; Hanchate et al., 2008) selected independent variables including age, sex, race or ethnicity and educational level, all of which had been previously found to be strongly correlated with low health literacy (Kutner et al., 2006). Miller et al. (2007) utilized data from the 1997 Medicare Health Literacy Study (MHLS), with s-TOFHLA scores for over 3,200 Medicare enrollees, to develop a predictive model for functional health literacy (FHL) using multiple logistic regression. The final predictive FHL model had an area under the ROC curve of 73.5% for accurately identifying older individuals with inadequate health literacy. Using the same national database (MHLS) and demographic predictor variables, Hanchate et al. created the Demographic Assessment for Health Literacy (DAHL), a proxy score, which closely approximated the measured health literacy scores from the MHLS. The lowest DAHL score correctly identified 79% of those with inadequate health literacy s-TOFHLA scores, with 59% sensitivity and 84% specificity. The area under the receiver operating curve was 0.81 (95% CI= 0.79-0.83), demonstrating the success of the model to predict those with higher and lower s-TOFHLA scores. Using the 2003 NAALs data, Martin et al., (2009) analyzed an expanded number of demographic factors (all aged adults, marital status, rurality, language spoken in the home and length of time as U.S. resident) associated with health literacy level, using linear regression to predict mean health literacy scores and a multivariable probit model to predict health literacy level. Findings from the linear and probit

multivariate models accounted for twice the variance (30% and 21% respectively) in health literacy scores compared with a model using only education as the predictor (15.5% and 10%).

These three statistically significant quantitative models were developed to examine the relationships between health literacy and health status, utilization, costs, outcomes and direct community level efforts for low health literate U.S. populations. These studies have limitations for the Hawai'i specific context. Between 0-3% of their samples were classified as "Asian or Other Pacific Islanders" and the common analytic approach of combining this heterogeneous population into one group undermines the usefulness of any results in understanding discrete disparities (Ghosh, 2010; Davis et al., 2016). From a population perspective, the inability to clearly discriminate between groups of people with different levels of health literacy may impede outreach efforts aimed at high risk cohorts (Jordan et al., 2011; Sentell et al., 2013). The use of available predictive models cannot be expected to successfully capture Hawai'i's unique and expanding population, with nearly 60% being of Asian or Native Hawai'ian or Other Pacific Islander ancestry (Ghosh, 2010; Jones & Bullock, 2012).

Creating a Hawai'i-specific demographic predictive model would allow the estimation of health literacy status in the samples engaged in major health research and surveillance in Hawai'i (i.e.; Kuakini Honolulu Heart Program, Honolulu-Asia Aging Study, Hawai'i BRFSS), and the activities of collaborative research efforts such as those of the Center for Native and Pacific Health Disparities Research of Native Hawaiians and other Pacific Peoples (Kaholokula, 2008). Future Hawai'i population-based studies may benefit from the addition of health literacy proxy measures to address individual and population health outcomes, resource planning, and

evaluation of interventions (Ghosh, 2010; IOM, 2015, p. 92). The specific aims of this study are to identify demographic variables associated with low health literacy and develop a multivariable predictive model for low health literacy in Hawai'i's adult population.

METHODS

Study Design and Population: Study data were obtained from the Hawai'i Health Survey (HHS). This is an annual population-based survey modeled after the National Health Information Survey. The HHS has been conducted by the Hawai'i State Department of Health, Office of Health Status Monitoring (OHSM) since 1968, and obtains demographic and health information on randomly selected Hawai'i respondents and their household members. The sample data are weighted based on population estimates provided by state of Hawai'i and U.S. Census data, to correct for under-sampling of certain populations, and to provide representative data for adults, households and age groups in the Hawai'i study population. This continuous statewide household survey is intended to provide the Hawai'i Department of Health (DOH) programs, community agencies, and the public with a statistical basis for planning and evaluation of health services and programs, as well as current data for health research projects.

The respondent must be an adult, 18 years of age or older who is knowledgeable about their household and able to provide core sociodemographic information. Core variables include: gender, age, income, ethnicity, education, household size, insurance status, income/ poverty status, and health status. Ethnicity, income/ poverty status, and health insurance variables are developed from multiple coded survey items and reported using algorithms based on American

Community Survey methods (http://health.hawaii.gov/hhs). The Community of American Survey Research Organizations (CARO) completion rates for the HHS were 40.1% (2008, N=5,954) and 29.9% (2010, N=5,987), with the rate difference explained by the inclusion of "cell phone only" households in 2010 (Sentell et al., 2013; HHS, 2010). The survey is administered in English, which excluded 4% of households contacted due to lacking English language proficiency to answer interview questions. The final survey sample from the years 2008 and 2010 was N=11,941. The variables used to create the predictive model for health literacy are shown in **Table 1**.

Outcome Variable – Health Literacy: Health literacy status was measured by using the Single Item Literacy Screening (SILS). Four of the total 225 question survey incorporated validated single item health literacy screening questions. The outcome measure (dependent variable) was coded as a binary indicator (adequate/inadequate) for health literacy using a single self- reported health literacy item: "How confident are you filling out medical forms by yourself?" The original survey by Chew et al. (2004), scored responses based on a 5 point Likert scale (1=Not at all, 2=A little bit, 3=Somewhat, 4=Quite a bit, 5=Extremely). Modeling the original SILs data, the cutoff score of ≤ 3 (somewhat) was coded as having increased risk of low health literacy, and a score of ≥ 4 was used as evidence of adequate health literacy. This single item question has been validated using the Short Test of Adult Functional Health Literacy (sTOFHLA) and Rapid Estimate of Adult Literacy (REALM), both frequently used tests for health literacy. These tests had AUROCs of 0.80 (95% CI=0.67–0.93) and 0.84 (95% CI=0.79–0.89) respectively, for detection of inadequate level of health literacy (Chew et al., 2004; Chew et al., 2008). For this

study, the dependent variable was coded to reflect poor health literacy status at cutoff score of ≤ 3, and ≥ 4 as adequate health literacy.

Predictor Variables – Sociodemographic Factors: The sociodemographic predictors for this study were selected if they met at least two of four inclusion criteria. The criteria included: (1) variable inclusion in larger studies of health literacy (NALS 1992; NAALs 2003; Prudential Medicare Study 1997; California Health Interview Survey 2007) (Kirsch 1993; Kutner et al., 2006; Wolf, Gazmararian, & Baker, 2005; Scott, Gazmararian, Williams, & Baker, 2002; CHIS 2011) or other predictive models of health literacy (Hanchate et al., 2008; Miller et al., 2007; Martin et al., 2009); (2) the variable had previously been found to have association with health literacy status (Gazmararian et al., 1999; Howard et al., 2006; Bennett et al., 1998; DeWalt et al., 2004; Sudore et al., 2006a: Sudore et al., 2006b); (3) the variable was identifiable in Hawai'i's demographic makeup, and (4) the variable was captured by HHS survey data in years 2008 and/or 2010.

Age: Age, typically a universally captured demographic variable, met all 4 inclusion criteria. For this study, it was reported as a continuous variable (18-105), based on respondent's age at last birthday. The adults were coded into the groups of young, 18-24 years; middle, 25-64 years; older, 64-84 years; and oldest, 85 years and older, as had been previously performed by Sentell et al. (2011) when reviewing the 2008 Hawai'i cohort. Younger adults were separated from middle adults based on the NAALs (2003) categorization in which completion of schooling was considered important in determining its possible effect on literacy status. The middle, older and

oldest adult divisions were designated to allow comparison for age cohorts with regard to level of education, poverty or immigration status.

Gender: Gender, a variable commonly reported in health literacy studies or predictive models, has been shown to be associated with health literacy status and was available in the HHS data during the years of interest. For this analysis, gender was self-reported by participants as either "male" or "female" in accordance with current U.S. Census 2010 collection methods (Howden & Meyer, 2012).

Race/Ethnicity: Report of minority race or ethnicity as a core independent variable in national surveys and predictive models has been consistently associated with lower health literacy in those analyses and in Hawai'i based studies of health literacy (Kutner et al., 2006; Martin et al., 2009; Sentell et al., 2011; Gazmararian et al., 1999; Bennett et al., 1998; Tai-Seale, Freund, & LoSasso, 2001). During the HHS interview, respondents' self- reported race/ethnicity was captured by answering the question "What race do you consider yourself to be?" The survey provided 21 distinct race/ethnic options for selection. This method for self- identification of race/ethnicity is consistent with U.S. Census (Jones & Bullock, 2012) questions regarding race/ethnicity, allowing for both multiple selections and write-in responses; "What is (respondent's) race?" and "Which categories describes Person 1 (respondent)?" While 23% of Hawai'i's total population claims more than one race on U.S. Census 2010 data (Hixson, Hepler, & Kim, 2012), for purposes of this study, only the respondent's answer to self-identified race was utilized. From these data, 7 major categories were coded based on frequencies of response for self-identified race/ethnicity, including: "White"/ "Native Hawaiian"/ "Chinese"/ "Filipino"/

"Japanese"/ "Other AA/PI" (includes Korean, Vietnamese, Asian Indian, Other Asian, Samoan or Tongan, Guamanian or Chamorro, Other-Pacific Islander)/ and "Other" (which includes Black or African American, Native American, Puerto Rican, Mexican, Other, Insisted Mixed). For those persons who declined to identify a racial or ethnic group, their response was recorded as "Refused."

Marital status: Another common demographic variable, marital status, has been associated with health literacy status and was available in the HHS survey (Martin et al., 2009; Kutner et al., 2006). The interviewee was asked "What is your marital status?" Responses were coded dichotomously for "married" or "not married." Further delineation of respondent's unmarried response was available through the HHS survey, however in this study binary coding was selected to more closely reflect large scale health literacy research categorization of marital status (Kutner et al., 2006) and subsequent predictive models based on national samples (Martin et al., 2009; Hanchate et al., 2008).

Education: Level of educational attainment has been shown to be associated with health literacy status, with studies showing adults who had graduated from high school or its equivalent having higher levels of health literacy compared to those with less than high school graduate level education. Health literacy typically improves with each additional level of education achieved (Nielsen-Bohlman et al., 2004, p. 63). Those adults who had not attended or complete high school demonstrated lower health literacy levels (Kutner et al., 2006; Dewalt et al., 2004; Schillinger, Barton, Karter, Wang, & Adler, 2006; Martin et al., 2009). Asking HHS participants, "What was the highest level of education you completed?" reflects the U.S. Census Bureau (U.S.

Census Bureau, 2015) collection techniques, dividing educational attainment into elementary school, secondary school and post-secondary education levels. Coding this variable using the benchmarks "less than high school, high school completion or equivalency, and greater than high school" was aligned with population based health literacy studies (Kutner et al., 2006; Gazmararian et al., 1999; Howard et al., 2006) and Hawai'i's adult population with over 85% having completed high school (U.S. Census Bureau, 2015).

Health Insurance Status: Health insurance status, also reported in national and regional surveys as having a connection with health literacy status (Kutner et al., 2006; Williams et al., 1995; Baker et al., 1998), was captured from 17 questions on the HHS interview. The Office of Health and Statistics Management coded the responses from health policy information, public or private, and self- reported health benefits, which resulted in a dichotomous result of insured=1 or uninsured=0.

Poverty or near poverty status: Socioeconomic status, often reported as either income or poverty status in studies on health literacy, met three of the inclusion criteria. The self-reported pre-tax income for the previous tax year was collected in the HHS interview and the Hawai'i Office of Health Statistics Management (OHSM) utilized this dollar amount, combined with household size questions to calculate poverty /near poverty status. The calculations were based on the U.S. Department of Health and Human Services poverty guidelines, a simplified version of the U.S. Census Bureau poverty thresholds, published for the state of Hawai'i in 2009 and 2010. HHS categorized the levels as: "Below Poverty–Poor=<100% Federal Poverty Level (FPL)"; "Near Poor=100-199% FPL"; "Middle and High Income >199% FPL"; or "Unknown"

(https://aspe.hhs.gov/poverty-guidelines). For analysis of the lower socioeconomic status, the variable was coded dichotomously: "below or near poor levels" =1 and "middle/high incomes" =0. These delineations were modeled after federal and state use of percentages of the FPL to determine eligibility for many social service programs, including Medicaid. In Hawai'i's Medicaid program, eligibility begins at family income of 133% of FPL for adults (https://www.healthinsurance.org/hawaii-medicaid/).

Living in rural area: Living in a more rural area has been associated with health literacy status in national studies (Kutner et al., 2006; Zahnd, Scaife, & Francis, 2009), and in one predictive model of health literacy (Martin et al., 2009). The HHS collected residence information by island, meeting 3 of the 4 criteria for inclusion in this study. Notably, there are 3 urban areas in the state of Hawai'i, using U.S. Census Urban and Rural Classification Criteria (U.S. Census 2012), which are on the islands of Oahu (Honolulu county-2) and Maui (Kahului-1). However, the information obtained from HHS respondents only designated island of residence. To assure inclusion of this important variable in the study, a review of Hawai'i's population data revealed the highest concentration of urban dwelling persons was on Oahu (96% of the islands' 953,000 population) and less than 1% of Oahu's residents resided in rural areas (U.S. Census 2012). Based on this differential, residence on Oahu was designated as "urban" and the neighbor island respondents reflected more "rural" based residence, coded as Neighbor islands= "0", "Oahu= "1".

Migration status: Immigrants, especially more recently arrivals, have been documented to struggle with the American healthcare system. The intricacies of culture, language, and access

issues combined with lower health literacy status have been suggested causes (Ku & Matani, 2001; Derose et al., 2009; O'Fallon, 2005; IOM, 2003, p. 125-126). With nearly 20% of Hawai'i's population born outside the U.S., reflective of the state's diverse population, this variable was included in the study (U.S. Census Bureau 2015). The HHS interviews captured the data with responses to the question, "Where were you born?" and results were separated to reflect U.S. born vs. immigrant Yes=U.S. born vs. No=non-U.S. born.

Statistical Analysis: The health literacy model was constructed using pre-selected commonly collected socio-demographic variables available in population surveys both in Hawai'i and nationally. Data analysis was conducted using SAS version 9.4 using the strata and weights from the HHS survey to account for the complex survey design. The weighted analyses provide results representative of the adult population of Hawai'i (excluding households without telephones, group quarters, homeless, and the island of Ni'ihau). The reported study percentages represent adjusted and weighted estimates.

The analyses first examined the distributions of the dependent variable, health literacy, and independent socio-demographic variables including age group, gender, marital status, education, race or ethnicity, poverty status, health insurance, urban-rural residence, and migration status. Next, each categorical variable was examined for association with low health literacy using chi-square tests. Subsequently, univariate logistic regression models were performed including single predictor variables and testing for statistical significance ($p<0.05$). This step was performed for information and not as part of a variable selection procedure, as the independent variables to be included in the multivariable model had been pre-selected to mirror

variables in national health literacy predictive models and the availability in Hawai'i population studies. Finally, a multivariable logistic regression model was constructed including all of the sociodemographic variables.

Based on national studies citing lower health literacy due to advanced age and /or immigration status, two subgroup analyses were performed: One model restricted the population to ages 65 years and above, whereas the other model was run only with 2010 respondents and examined migration status, which was only available in the 2010 survey. All models were assessed the accuracy of prediction by comparing the Area Under Receiver Operating Characteristics (AUROC) curves. Finally, the stability of the models was determined by cross validation using a modified split model application for the HHS data set (Palmer & O'Connell, 2009). The HHS population was randomly split into an exploratory group, comprising 70% of total population and the remaining 30% assigned to a validation group. The AUROC values were compared for model stability.

RESULTS

A description of the study population is provided in **Table 2.** Low health literacy was found in 18% of the sample. The study sample had nearly equal gender distribution. Almost 70% were in the 25-64-year-old age group and over 58% were unmarried. Regarding education, 4% reported less than 12th grade level achievement, 29% completed high school or a Graduate Equivalency Degree (GED), and 67% indicated attending training beyond high school level.

Ethnic distribution was: White 28%, Japanese 24%, Hawaiian 15%, Filipino 14%, Chinese 6%, "Other Asian American/ Pacific Islanders" ("Other AA/PI") 4%, and "Other" 9%. Near poverty or poverty status was found in almost 30% of respondents. Most respondents (over 94%) reported a form of health insurance coverage. Over two thirds of persons lived on Oahu, an urban area. The majority of respondents (87%) were born in the United States.

As shown in **Table 3**, low health literacy status was significantly more common in those at both ends of the age spectrum, seen in younger (18-24 years) and older (85+ years) adults compared to those ages 25-64 and 64-84 years old. There was no difference in low health literacy by gender in descriptive analyses. Those who were married were less likely to have low health literacy than those who were unmarried. Low health literacy was also significantly associated with lower educational attainment; Native Hawai'ian, Chinese, Filipino, Japanese, "Other AA/PI" and "Other" ethnicities compared to White ethnicity; lack of health insurance; poor or near poor economic status and living in rural areas. A significantly higher percentage of foreign born respondents had low health literacy compared with those born in the U.S.

We applied multivariable logistic regression models, shown in **Table 4a**, with low health literacy as the outcome variable for the whole survey population (2008 and 2010). There was an increased odds of low health literacy for those aged 85 years or older (OR= .85, 95% CI=1.28-2.69, p=0.001) compared to 25-64 year olds. Those ethnically self-identified as Chinese (OR=2.32, 95% CI=1.42-3.79, p=0.001), or Filipino (OR=2.14, 95% CI=1.55-2.95, p=<0.0001), were over twice as likely to have low health literacy compared to those who were White. There were statistically significant increased odds of having low health literacy for Japanese (OR=1.66,

95% CI=1.26-2.18, p<0.0001), "Other AA/PI" (OR=1.84, 95%CI=1.02-3.31, p=0.041) and "Other" (OR=1.44, 95% CI=1.02-2.06, p=0.043) ethnicities compared to Whites. Adults not having completed high school or its equivalent (OR=2.10, 95% CI=1.24-3.55, p=0.005) as compared to high school graduates, also had increased odds of low health literacy. Rural residence conferred an increased risk of low health literacy status compared to urban dwellers (OR=1.3, 95% CI=1.07-1.58, p=0.003). While being Native Hawaiian as compared to White, or uninsured compared to having health insurance, or being poor compared to those with higher incomes, increased the likelihood of having low health literacy, none of these reached statistical significance in this study population.

In **Table 4b**, the multivariable logistic regression models for the study population for only the 2010 sample, which allowed the inclusion of the immigration status variable, revealed statistically significant risk for having low health literacy for those who were immigrants compared to those who were U.S. born (OR=1.67, 95% CI=1.03-2.74, p=0.035). Native Hawaiians, Chinese, Filipino, Japanese, "Other AA/PI" and "Other", exhibited a 2 to 4-fold greater risk of low health literacy in this subgroup analysis compared to Whites, reaching statistical significance for all groups except for the "Other AA/PI" population. Persons who did not complete high school had higher odds of low health literacy (OR=2.69, 95% CI=1.29-5.6, p=0.008) compared with high school graduates, and conversely, any post high school education significantly decreased the odds of low health literacy (OR=0.40, 95% CI=0.288-0.57, p<0.0001) compared to those who finished high school. Those reporting no health insurance were 2.5 times as likely to have low health literacy as insured respondents. Living in a rural area compared to

urban residence increased the odds of having low health literacy. Both older (65-84 and 85+ years) and younger (ages 18-24 years) respondent groups had increased odds ratios for low literacy compared with middle aged (25-64 years old) persons, though neither age group reached statistical significance.

Subgroup analyses of only respondents aged 65 years and older are illustrated in **Table 5a**. The multivariable logistic regression models predicting low health literacy revealed the oldest study participants, aged 85+ years, had higher odds of low health literacy compared to the "younger "old aged group (ages 65-84 years) (OR=1.55, 95% CI=1.09-2.26, p=0.014). Those who did not achieve high school graduate status were twice as likely to exhibit low health literacy (OR=2.04, 95% CI=1.33-3.11, p=0.001) compared to those who completed high school or its equivalent, while educational attainment beyond high school was protective against low health literacy (OR=0.38, 95% CI=0.28-0.53, p<0.0001). Older Native Hawaiians were less likely to have low health literacy (OR=0.59, 95% CI=0.36-0.96, p=0.035) while older persons in the "Other AA/PI" category had over 2.5 times increased odds of lower health literacy (OR=2.65, 95% CI=1.24-5.88, p=0.014) compared to Whites. All the remaining non-White ethnicities had increased odds ratios associated with low health literacy but none achieved statistical significance. Older persons who were either uninsured, of lower socioeconomic status or rural residence, also had higher odds ratios for low health literacy, though no variable achieved statistical significance. Male gender was associated with lower risk of low health literacy, as was unmarried status, without reaching statistical significance.

Additional subgroup analyses were performed on this older cohort which included migration status data from survey year 2010, represented in **Table 5b**. These multivariable logistic regression models show increased odds ratios for the oldest respondents aged 85+ years having low health literacy, compared to those aged 65-84 years, but this did not reach statistical importance. In this subgroup model, neither gender nor marital status conveyed significant impact on health literacy level. Educational attainment less than high school completion remained significantly predictive of low health literacy (OR=2.16, 95% CI=1.14-4.10, p=0.018) compared with high school graduates, while any education beyond high school was associated with reduced risk of low health literacy (OR=0.43, 95%CI=0.27-0.67, p=<0.0001). Older Native Hawaiians continued to have a lower odds ratio predictive of lower risk for low health literacy compared to Whites, but it did not reach statistical significance. Ethnic groups, including Chinese, Filipino, Japanese, "Other AA/PI" and "Other", had higher odds ratios predictive for low health literacy, but only those respondents ethnically identified as "Other" had a statistically significant result (OR=2.40, 95% CI=1.27-4.70, p=0.011). Immigration status, poor or near poor economic level and rural residence all had increased but not significant odds ratios for low health literacy when compared with U.S. born, higher income and urban dwellers respectively.

Presented in **Table 6** are the values of the area under the receiver operating characteristic (AUROC) curves for the entire study population and the subgroup populations including the split model cross validation results. The accuracy of prediction for the all-inclusive study population model found that the AUROC curve was equal to 0.689 in the exploratory group and 0.686 in the validation sample (**Figure 1)**. In the subgroup model for age over 65 years only, the AUROC

curve was 0.624 in the exploratory group and 0.641 in the validation population. For the migration model (2010 only) inclusive of all ages, the AUROC curve was 0.684 in the exploratory sample and 0.683 in the validation sample. The final predictive migration model (2010 only) for low health literacy in those age 65+ years found that the AUROC curve was 0.647 in the exploratory sample and 0.610 in the validation sample. shows the results of the health literacy predictive

DISCUSSION

Using state-wide health survey data, this study identified demographic variables in Hawai'i's adult residents associated with low health literacy and applied multivariable predictive models for low health literacy in the state's unique multi-ethnic population. There are several notable findings from the data and subsequent analyses which were distinguishable in the Hawai'i survey compared to national health literacy studies.

First, low health literacy was present in 18% of the study population, which is substantially below mainland estimates stating that one third of all U.S. adults have low health literacy. In subgroup analysis, 48% of Hawai'i's respondents age 65 and older had low health literacy, which is appreciably less than national estimates in which two-thirds of older Americans struggle with health literacy (Kutner et al., 2006). This difference may be reflective of the higher level of educational achievement found in this Hawai'i study population, where 66% of participants reported greater than high school education, compared to the national average of 59% (U.S. Census Bureau 2015). This incomparability extends to other socio-economic factors

usually associated with low health literacy including; the percent of persons found to be "poor" in Hawai'i versus national data, 10% vs 15.3%, respectively, and those without health insurance in Hawai'i versus national reports, 8% vs 16%, respectively (Sober & Tomczyk, 2013).

Second, Hawai'i's survey respondents were predominantly of non-White ethnicity, and 75% self-identified as one of sixteen possible non-White or mixed-race categories. This disaggregation of ethnic groups allowed for the improved identification of literacy levels in sub-groups not commonly found in larger health literacy studies. Ethnic data analysis reveals that between 70 to 80% of all Hawai'i's non-White ethnic groups had adequate health literacy, higher than prior estimates for aggregated AA/PI data presented in national studies (Kutner et al.,2006; Hanchate et al., 2008; Martin et al., 2009). In the Hawai'i data, those self-identified as Chinese, Filipino, and "Other AA/PI" designation were found to have larger percentages of respondents with low health literacy compared with Whites, Hawaiians, Japanese and "Other". In the multivariable regression analysis, these same groups along with Japanese and "Other" designations had statistically significantly increased odds of low health literacy compared to Whites ($p<0.05$). The association between non-White ethnicities and lower health literacy is a widely reported finding in large population studies (Kutner et al., 2006; Hanchate et al., 2008; Miller et al., 2007; Martin et al., 2009). Within the logistic regression model which included immigration data (OHSM 2010), the "Other AA/PI" classification was no longer significant for lower health literacy status. From other health literacy studies of immigrants, the level of English language proficiency and length of residence in the United States are suggested factors which may contribute to low health literacy, though these demographics were not obtained in the HHS

survey (Sentell et al., 2011; Martin et al., 2009; Shaw, Huebner, Armin, Orzech, & Vivian, 2009).

Importantly, there were similarities between national studies and Hawai'i's survey regarding the socio-demographic factors predictive for low health literacy. Within the HHS whole population multivariable logistic regression model, the demographic components with increased odds of having low health literacy included older age, males, unmarried status, rural residence, and lower level of education. In the Hawai'i migration subgroup analysis, being born outside of the U.S. and lack of health insurance were significantly associated with increased odds of having low health literacy. This is also comparable to national data in which the uninsured and immigrant populations are at risk for low health literacy (Nielsen-Bohlman et al., 2004, p. 113; Kutner, et al., 2006). Compared to national predictive models for health literacy, Hawai'i's logistic regression models did not identify low economic status as a statistically significant predictor for low health literacy (Martin, et al., 2009).

Based on prior U.S. population studies which revealed that older Americans are disproportionately affected by low health literacy, even after controlling for level of educational attainment and socio-economic status (Martin et al., 2009; Hanchate et al., 2008; Sudore et al., 2006a; Sudore et al., 2006b: Kutner et al., 2006; Gazmararian et al., 1999), this study separately analyzed data for Hawai'i's respondents aged 65 years and older which comprised 20% of the total study population, a close approximation of the state's older population for the same year (U.S. Census 2015). In both univariate analysis and multivariable logistic regression models, the oldest HHS interviewees (aged 85 years and older) had higher odds ratio of low health literacy, a

finding which mirrors the results of national studies of Medicare managed care enrollees (Gazmararian et al., 1999; Hanchate et al., 2008). In this older cohort, as in the whole population models, education and ethnicity were found to have statistically significant associations with health literacy status. Lower educational attainment and non-White ethnicity, specifically the "Other AA/PI" group, had higher odds of low health literacy, while being ethnic Hawaiian and possessing greater than a high school level of education were equated with lower odds of low health literacy. The influence of educational achievement on health literacy has been well documented in larger population studies, while the lower health literacy in "Other AA/PI" individuals may be related to the aggregation of 46 distinct groups in this category (Hixson et al., 2012). The finding of lower risk of health literacy in older Native Hawaiians was unexpected, and should be explored further in this ethnic group, who are reported to have the shortest life expectancy among Hawai'i's population (Wu, Braun, Onaka, Horiuchi, Tottori, & Wilkens, 2017; Park et al., 2009).

In further subgroup analysis inclusive of place of birth and in the older population, migration pattern did have higher odds of low health literacy but did not meet statistical significance. The ethnic "Other" designation was the only category to have statistically significant higher odds of low health literacy compared to Whites. This ethnic grouping includes both African Americans/Blacks and Hispanic respondents, groups with documented higher risk of low health literacy in national studies (Kutner et al., 2006; Bennett, Chen, Soroui, & White, 2009; Hanchate eta al., 2008; Miller et al., 2007; Baker, Wolf, Feinglass, Thompson, Gazmararian, & Huang, 2007; Sudore et al., 2006a). Similar to the total population migration

model, the older age immigrant model revealed that educational attainment, less than high school or greater than high school, was associated with either a higher or lower risk of low health literacy respectively (Kutner et al., 2006; Bennett et al., 2009; Sentell et al., 2011).

Notable differences in Hawai'i's older aged subgroup compared to the whole population models, were the influences of gender and marital status on health literacy. In Hawai'i's whole population model, being male or unmarried were both significantly associated with low health literacy versus in the analysis involving only the older group, being male or unmarried both had a shielding, though non-significant effect, for low health literacy. These trends also deviated from U.S. national studies of the elderly (Baker et al., 1998; Gazmararian et al., 1999; Kutner et al., 2006; Sudore et al., 2006a: Sudore et al., 2006b). Among Hawai'i's diverse ethnic cultures, the older generation is less likely to live alone compared with national counterparts, and these living situations may confer protection regarding health literacy status (Braun, Kim, Ka'opua, Mokuau, & Brown, 2015; Yuan, Karel, & Yuen, 2007).

The second goal of this study of Hawai'i's adults was to develop predictive models for low health literacy, using demographic and socio-economic variables commonly collected in population based research. Based on of the unique features of Hawai'i's population, with higher percentage of elderly and higher migration status, four models arose. Performance of the four multivariable predictive models was assessed using a generally accepted measure for predictive accuracy, the area under the receiver operating characteristic (AUROC) curve. This method also allowed for control of confounding variables (Hajian-Tilaki, 2013). The stability of each model was accomplished through cross validation. Using a split model technique, a validation group

was randomly selected from the same population, and model stability established by comparing the AUROC for each sample (Palmer & O'Connell, 2009).

The four models achieved fair levels for diagnostic accuracy in their prediction for low health literacy status. The highest values were for the whole population model with an AUROC=0.69, and whole population with migration model with an AUROC=0.69, with similar results in their respective validation groups, establishing the stability of the models. In the sub-groups, the older adult whole population model had an AUROC=0.62 and the older migration model yielded an AUROC=0.65, with stability of the models confirmed by comparable AUROCs in the respective validation populations. Though independent variables were found to have a statistically significant association with low health literacy, and multivariable logistic regression yielded increased odds ratios for low health literacy status, odds ratios are not capable of accurate detection or prediction (Pepe, Janes, Longton, Leisenring, & Newcomb, 2004). The models' lower discriminatory capacity may reflect the "en bloc" inclusion of selection of variables used in national health literacy predictive models, and may not accurately depict Hawai'i's adult population. Utilizing another method for model building with precise selection of covariates from the HHS dataset could provide a more robust prediction model for health literacy in Hawai'i.

Detailed comparison of these state specific multivariable logistic regression models with the other published national studies for predictive models for health literacy revealed several important distinctions (Hanchate et al., 2008; Miller et al., 2007; Martin et al., 2009). While all the studies included four common independent variables; age, gender, education, and race or

ethnicity; the race designations of the national study populations were limited to: "White," "Black," "Hispanic" and "Other." Only Martin et al. (2009) reported aggregate data for "AA/PI" (3.4%) of the study population, contrasted with a predominance of HHS respondents who would be classified by Martin et al. (2009) as "AA/PI" (63%), limiting applicability of the other predictive models in Hawai'i's population. HHS data analysis and the reviewed studies did share several strong associations for low health literacy with the same independent variables (lower educational attainment, older age and non-White ethnicities). Of the national predictive studies, Martin et al. (2009) developed models which included additional demographic predictors similar to those available in Hawai'i's survey (all ages, marital status, poverty indices, immigration status and rural residence). Martin et al. (2009) reported similar findings to Hawai'i's population, with statistically significant associations with lower health literacy and being unmarried or claiming immigrant status. Lower income level was found to be associated with low health literacy in both studies, though it only reached statistical significance in the national study. Rural residence was significantly associated with lower health literacy in Hawai'i but not in the national analysis conducted by Martin et al. (2009). This difference is likely due to the more discrete assessment of rurality available for Hawai'i versus the limitations of the dichotomous measure used in a large national survey (Martin et al., 2009).

Hawai'i models did not meet the same predictive accuracy for detecting low health literacy in older adults as those proposed by Hanchate et al. (2008) and Miller et al. (2007), which yielded AUROCs equal to 0.80 and 0.74, respectively. Hawai'i's older adult models report an AUROC of 0.62. Review of Hanchates' and Millers' older adult's populations revealed

better health literacy levels (inadequate health literacy 25%) and markedly different ethnic configuration (Whites 77%) in contrast to Hawai'i's older adult participants (inadequate health literacy, 48%; Whites, 28%) which may contribute to the dissimilarity in model application. Additionally, Miller et al. (2007) examined and included key interaction variables (i.e., age*education, race*education) in the final model. This step, not performed in this study's analyses, applied to the unique demographics of Hawai'i would enhance the exploratory stages of model building (Sentell, Dela Cruz, Heo, & Braun, 2013; Ghosh, 2010; Park et al., 2009).

Strengths: There are multiple strengths of this cross-sectional population study which contains a large sample size of AAPI. This is the first attempt to develop a predictive model for low health literacy using socio-demographic variables which have been associated with low health literacy in Hawai'i adults (Sentell et al., 2011; Sentell et al., 2013). Secondly, these models add to prior Hawai'i based research by performing subgroup analyses in older adults and by migration status, reflecting national models developed for predicting health literacy (Hanchate et al., 2008; Martin et al., 2009; Miller et al., 2007). Models from the subgroup analyses reveal the variability of low health literacy across disaggregated Asian American, Hawaiian and Pacific Islander ethnicities. The study also exposes the restricted applicability of national models to Hawai'i's predominantly non-White residents and further supports the collection and analysis of disaggregated data in Asian American, Hawaiian and Pacific Islander subpopulations to better understand the health status and needs of Hawai'i's varied adult population (Braun et al., 2015; Ghosh, 2003: Ghosh, 2010).

Limitations: This research has several limitations. The selection of demographic variables to reflect national studies of health literacy, with markedly different racial and ethnic cohorts, may not adequately represent the uniqueness of Hawai'i's adult population. The interviews were conducted in "English only" which also limited complete appraisal of the population. Capturing the influence of culture, language, community and immigration characteristics, all of which have been found to impact non-White ethnic populations' health experiences would strengthen the health literacy assessment of Hawai'i's diverse population (DeRose et al., 2007; Choi, 2008; Yamada, 2009; Martin et al., 2009; Sentell et al., 2011; Sentell et al., 2013; Lee, Choi, & Lee, 2015). While this study design attempted to disaggregate ethnic data for Asian Americans, Hawaiians and other Pacific Islanders, the study category for "Other AA/PI" may contain over 50 distinct ethnic groups for those self-identified as "Other-Pacific Islander." (Braun et al., 2015). Although the HHS data were weighted to allow for adequate representation of the Hawai'i adult population, the small percentage of respondents in the "Other AA/PI" category (4.4%) included in the final study population, limits the applicability of the predictive model to this very diverse group. Lastly, the assessment of health literacy with the Single Item Literacy question (SILs), "How confident are you at filling out medical forms?" is a self-reported measure subject to bias. While screening by this method reduces the burden of direct testing, the validity is limited with the results providing information about respondents' challenges with health care related tasks and not actual health literacy abilities (Isikawa& Yano, 2008; Sentell et al., 2011). The SILs, proven to outperform educational attainment in detection of lower health literacy, was tested predominantly in older White male populations (Chew et al., 2004; Chew et al., 2008;

Wallace et al., 2006) and needs validation in Hawai'i's diverse adult population (Sentell et al., 2011).

This research represents an important step for understanding and predicting the health literacy of Hawai'i's adult population. The illumination of Hawai'i specific socio-demographic factors associated with low health literacy, may provide health care providers, program administrators and researchers additional information for evaluating and meeting the needs of the populations they serve. Focused resource allocation, including staffing, health education and outreach programs could support clinical and public health interventions for adults at higher risk for lower health literacy.

While the predictive accuracy of this study's models did not achieve an acceptable level for discriminating low health literacy in Hawai'i adult population (Grzybowski & Younger, 1997), or application to other Hawai'i based research, it does direct the process towards strengthening a Hawai'i predictive model. The next step would be to deviate from national examples, and construct models which encompass the influences of Hawai'i's distinct community and cultural norms.

CONCLUSIONS

Health literacy impacts individual and community health. The development of methods to measure or estimate health literacy skills at the local level is needed to help determine its relevance within diverse groups. Advancing population predictors of health literacy status would provide health professionals in research, policy and practice an essential tool for cultivating interventions to foster better health outcomes.

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Figure 1. Health Literacy Predictive Model – Area under ROC curve (Whole population 2008 and 2010).

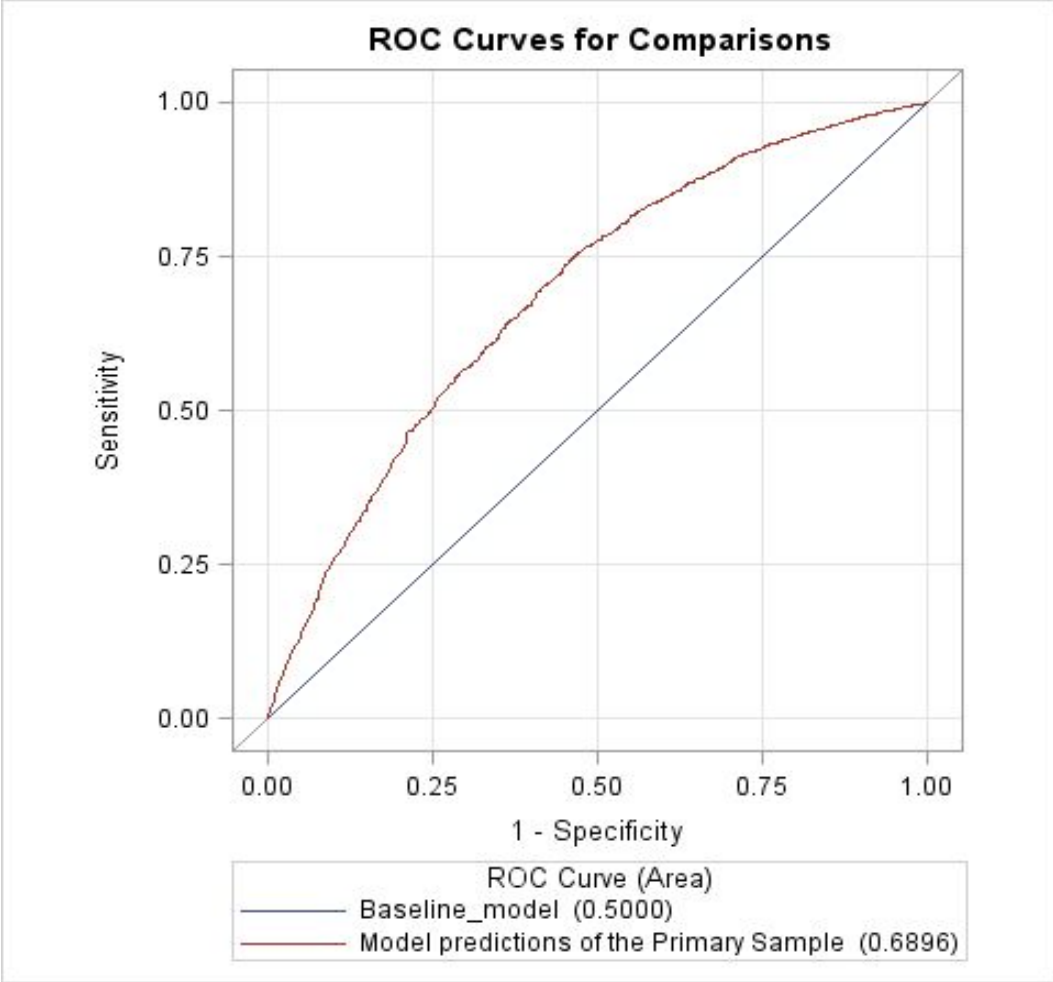
ROC Curves for Comparisons
Sensitivity
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
1 - Specificity
ROC Curve (Area)
Baseline_model (0.5000)
Model predictions of the Primary Sample (0.6896)

Table 1. Variables Used to Create Predictive Model for Health Literacy.

Variable Name	**HHS Questionnaire**	**HHS survey format for variable**	**Coding for statistical analysis for proposed model**
Health Literacy (O)	How confident are you filling out medical forms by yourself?	1 = Not at all 2 = A little bit 3 = Somewhat 4 = Quite a bit 5 = Extremely	Based on SILs data (Chew 2004) cutoff score of < or = to 3 ("somewhat") as having increased risk for low health literacy and 4, 5 as evidence of adequate literacy. Dichotomized variable: 1 = Low health literacy 0 = Adequate health literacy
Age (I)	What was your age in years on the last birthday?	Numerical age (years)	Divided into age groups for adults: Young = 18-24 years Middle = 25-64 years Older = 65-84 years Oldest = 85+ years
Gender (I)	Record sex of respondent	1 = Male 2 = Female	0 = Male 1 = Female
Marital (I)	What is your marital status?	1 = Married 2 = Member of an unmarried couple 3 = Widowed 4 = Divorced 5 = Separated 6 = Never Married 7 = Not old enough to be married 8 = Don't know 9 = Refused 10 = Same sex couple	Dichotomized variable to currently married vs all other categories: 0 = Unmarried 1 = Married

Education Level (I)	What is the highest grade of school completed?	1 = Kindergarten/ Preschool 2 = 8th Grade or Less 3 = Grades 9-11 4 = Grade 12 / GED 5 = College 1-3 Yrs. or Tech 6 = Bachelor's Degree (BA, BS) 7 = Graduate degree (MA, MS, PhD) 8 = Never attended school 9 = Don't know/refused	Divisions for educational levels designated: - <high school - HS or equivalency - >High school
Race (self) (I)	What race do you consider yourself to be?	01,15 = White 02,21 = Native Hawaiian 03 = Chinese 04 = Filipino 05 = Japanese 06 = Korean 07 = Vietnamese 08 = Asian Indian 09 = Other Asian 10 = Samoan/Tongan 11 = Black/African American 12 = Native American 13 = Puerto Rican 14 = Mexican 16 = Guamanian/Chamorro 17 = Other PI 18 = Other 22 = Insisted Mixed 19 = Unknown 20 = Refused	7 major categories were coded based on frequencies of response for self-identified ethnicity, including : -White -Native Hawaiian -Chinese -Filipino -Japanese -Other AA/PI (includes Korean, Vietnamese, Asian Indian, Other Asian, Samoan or Tongan, Guamanian or Chamorro, Other Pacific Islander) -Other (includes Black or African American, Native American, Puerto Rican, Mexican, Other, Insisted Mixed)
Poverty Level (I)	Self-reported pre-tax income for previous tax year	1 = Below Poverty - Poor <100%" 2 = Near Poor 100-199% 3 = Middle & High Income >199% 4 = Unknown	Office of Health Statistics Management (OHSM) used income/household size questions to code poverty/near poverty status based on UDHHS (2008, 2010) poverty cutoff guidelines for Hawaii: 1 = At or <199% of FPL 0 = Others

Insurance (I)	Any health policy lists a private health plan for Respondent.	1 = Private Insurance 0 = No Private Insurance	Insurance status was coded by Office of Health Statistics Management (OHSM) from information insurance related questions*; Variable was then dichotomized: 0 = No insurance 1 = Insurance
QUEST (I) *	Any health policy lists for QUEST for Respondent.	1 = QUEST Insurance 0 = No QUEST Insurance	
MEDICAID (I) *	MEDICAID	1 = MEDICAID Insurance 0 = No MEDICAID Insurance	
MEDICARE (I) *	Any health policy lists for MEDICARE for Respondent.	1 = MEDICARE Insurance 0 = No MEDICARE Insurance	
OTHERPLAN (I) *	Any health policy lists a plan that may be a health insurance policy for Respondent.	1 = Possible Health Care Plan Insurance 0 = No Other Plan/Insurance	
Island (I)	What island do you live on?	1 = Oahu 2 = Hawai'i 3 = Kauai 4 = Maui 5 = Molokai 6 = Lanai 7 = Other (specify) 8 = Refused	Dichotomized to reflect more rural vs. suburban/urban based residence: 0 = Neighbor islands 1 = Oahu
Where born (I)	Where were you born?	1 = in Hawai'i (any island) 2 = in another U.S. state 3 = in a U.S. territory 4 = in another country 8 = Don't Know/Not Sure 9 = Refused	Dichotomized variable to reflect US born vs immigrant: Yes = U.S. born No = non-U.S. born

Note: Independent Variable (I), Outcome Variable (O)

Table 2. Description of Study Population (2008 N=5,987, 2010 N=5,954).

Variable	Groups	Percent
Low Health Literacy	No	82.02
	Yes	17.97
Age Groups	18-24 years	10.67
	25-64 years	69.80
	65-84 years	15.64
	85+ years	3.88
Gender	Male	49.60
	Female	50.39
Marital Status	Not Married	58.41
	Married	41.58
Education	Less than High School	4.25
	High School	29.24
	Greater than High School	66.50
Ethnicity	White	28.27
	Hawaiian	14.65
	Chinese	6.35
	Filipino	14.17
	Japanese	23.63
	Other AA/PI	4.37
	Other	8.52
Poverty Level	Not Poor or Near Poor	70.29
	Poor or Near Poor	29.70
Health Insurance	No	5.91
	Yes	94.08
Urban or Rural	Not Oahu Resident	31.23
	Oahu Resident	68.76
Born in United States (available in 2010 only)	No	12.95
	Yes	87.04

*Note: All percentages are based on weighted HHS estimates.

Table 3. Description of Study Population by Health Literacy Status (2008 and 2010).

Variable	Groups	Health Literacy (HL) Status		P Value
		Adequate Health Literacy	Low Health Literacy	
Age Groups	18-24 years	71.50%	28.40%	<0.0001
	25-64 years	84.60%	15.40%	
	65-84 years	80.70%	19.30%	
	85+ years	70.70%	29.30%	
Gender	Male	80.82%	19.18%	0.1088
	Female	83.21%	16.78%	
Marital Status	Not Married	79.29%	20.70%	<0.0001
	Married	85.87%	14.12%	
Education	Less than HS	53.00%	46.99%	<0.0001
	High School	73.78%	26.21%	
	Greater than HS	87.51%	12.49%	
Ethnicity	White	88.16%	11.83%	<0.0001
	Hawaiian	82.17%	17.82%	
	Chinese	78.97%	21.02%	
	Filipino	73.23%	26.76%	
	Japanese	82.16%	17.83%	
	Other AA/PI	77.65%	22.34%	
	Other	80.20%	19.79%	
Poverty Level	Not Poor/Near Poor	84.64%	15.35%	<0.0001
	Poor/Near Poor	75.83%	24.16%	
Health Insurance	No	74.76%	25.23%	0.0082
	Yes	82.48%	17.51%	
Urban or Rural	Not Oahu Resident	79.36%	20.63%	0.0061
	Oahu Resident	83.24%	16.75%	

Born in US (2010 only)	No	64.55%	35.45%	0.0094
	Yes	80.04%	19.96%	

*Note: All percentages are based on weighted HHS estimates.

Table 4a. Multivariable Logistic Regression Model Predicting Low Health Literacy (Whole Population 2008 and 2010).

Variable	Odds Ratio	95% CI	P Value
Age Group 18-24 vs. 25-64 years	1.44	1.01 - 2.05	0.040
Age Group 65-84 vs. 25-64 years	1.23	1.01 - 1.51	0.036
Age Group 85+ vs. 25-64 years	1.85	1.28 - 2.69	0.001
Male vs. Female	1.24	1.01 - 1.51	0.034
Not Married vs. Married	1.25	1.03 - 1.51	0.018
Ed Level – < HS vs. HS	2.10	1.24 - 3.55	0.005
Ed Level – > HS vs. HS	0.47	0.38 - 0.58	<0.0001
Ethnicity Hawaiian vs. White	1.31	0.95 - 1.81	0.098
Ethnicity Chinese vs. White	2.32	1.42 - 3.79	0.001
Ethnicity Filipino vs. White	2.14	1.55 - 2.95	<0.0001
Ethnicity Japanese vs. White	1.66	1.26 - 2.18	<0.0001
Ethnicity Other AA/PI vs. White	1.84	1.02 - 3.31	0.041
Ethnicity Other vs. White	1.44	1.01 - 2.06	0.043
Uninsured vs. Insured	1.30	0.90 - 1.89	0.155
Poor or Near Poor vs. Not	1.23	0.99 - 1.53	0.059
Rural vs. Urban	1.30	1.07 - 1.58	0.003

Table 4b. Multivariable Logistic Regression Model Predicting Low Health Literacy (Whole Population 2010 only, including immigration status).

Variable	Odds Ratio	95% CI	P Value
Age Group 18-24 vs. 25-64 years	1.32	0.79 - 2.21	0.284
Age Group 65-84 vs. 25-64 years	1.15	0.84 - 1.56	0.373
Age Group 85+ vs. 25-64 years	1.53	0.84 - 2.77	0.159
Male vs. Female	1.31	0.96 - 1.78	0.085
Not Married vs. Married	0.97	0.73 - 1.27	0.828
Ed Level – < HS vs. HS	2.69	1.29 - 5.60	0.008
Ed Level – > HS vs. HS	0.40	0.28 - 0.57	<0.0001

Ethnicity Hawaiian vs. White	1.96	1.17 - 3.31	0.011
Ethnicity Chinese vs. White	4.00	1.76 - 9.10	0.001
Ethnicity Filipino vs. White	2.25	1.29 - 3.92	0.004
Ethnicity Japanese vs. White	2.37	1.48 - 3.79	<0.0001
Ethnicity Other AA/PI vs. White	2.02	0.84 - 4.83	0.112
Ethnicity Other vs. White	2.05	1.14 - 3.70	0.016
Uninsured vs. Insured	2.47	1.40 - 4.35	0.002
Poor or Near Poor vs. Not	0.90	0.65 - 1.25	0.561
Rural vs. Urban	1.52	1.12 - 2.08	0.007
Immigrant vs. Born in USA	1.67	1.03- 2.71	0.035

*Note: Based on weighted HHS estimates.

Table 5a. Multivariable Logistic Regression Model Predicting Low Health Literacy (Population Age 65+ only, 2008 and 2010).

Variable	Odds Ratio	95% CI	P Value
Age Group 85+ vs. 65-84 years	1.55	1.09 - 2.22	0.014
Male vs. Female	0.91	0.70 - 1.18	0.488
Not Married vs. Married	0.85	0.66 - 1.10	0.231
Ed Level – < HS vs. HS	2.03	1.33 - 3.11	0.001
Ed Level – > HS vs. HS	0.38	0.28 - 0.51	<0.0001
Ethnicity Hawaiian vs. White	0.59	0.36- 0.96	0.035
Ethnicity Chinese vs. White	1.62	0.90 - 2.91	0.102
Ethnicity Filipino vs. White	1.39	0.85 - 2.27	0.186
Ethnicity Japanese vs. White	1.08	0.78 - 1.50	0.627
Ethnicity Other AA/PI vs. White	2.65	1.21 - 5.80	0.014
Ethnicity Other vs. White	1.30	0.82 - 2.04	0.254
Uninsured vs. Insured	1.76	0.79 - 3.91	0.162
Poor or Near Poor vs. Not	1.32	0.98 - 1.77	0.064
Rural vs. Urban	1.20	0.95 - 1.52	0.123

Table 5b. Multivariable Logistic Regression Model Predicting Low Health Literacy (Population Age 65+ and 2010 only, including immigration status).

Variable	Odds Ratio	95% CI	P Value
Age Group 85+ vs. 65-84 years	1.37	0.80 - 2.33	0.241
Male vs. Female	0.75	0.51 - 1.09	0.137
Not Married vs. Married	0.74	0.52 - 1.05	0.094
Ed Level – < HS vs. HS	2.16	1.14 - 4.11	0.018

Ed Level – > HS vs. HS	0.43	0.27 - 0.67	<0.0001
Ethnicity Hawaiian vs. White	0.87	0.45 - 1.69	0.697
Ethnicity Chinese vs. White	2.38	1.02 - 5.53	0.044
Ethnicity Filipino vs. White	1.68	0.83- 3.43	0.148
Ethnicity Japanese vs. White	1.51	0.93 - 2.43	0.090
Ethnicity Other AA/PI vs. White	2.66	0.92 - 7.68	0.070
Ethnicity Other vs. White	2.40	1.22 - 4.70	0.011
Uninsured vs. Insured	2.18	0.57 - 8.26	0.251
Poor or Near Poor vs. Not	1.12	0.73 - 1.73	0.592
Rural vs. Urban	1.38	0.96 - 1.99	0.081
Immigrant vs. Born in USA	1.57	0.75 - 3.28	0.232

*Note: Based on weighted HHS estimates.

Table 6. Low Health Literacy Predictive Models – Area Under Receiver Operating Characteristic (AUROC) Curves.

Population	Exploratory Group	Validation Group
All Ages, Total Population	0.689	0.686
Age 65+ Population	0.624	0.641
Migration Model, All Ages (2010 only)	0.684	0.683
Migration Model, Age 65+ (2010 only)	0.647	0.610

Note: Exploratory Group (70% of total population) and Validation Group (30% of total population).