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Dietary Assessment of domoic acid Exposure: What can be learned from traditional methods and new applications for a technology assisted device

Carol J. Boushey^{1,*}, Edward J. Delp², Ziad Ahmad², Yu Wang², Sparkle M. Roberts³, and Lynn M. Grattan³

¹Epidemiology Program, University of Hawaii Cancer Center, 701 Ilalo Street, Room 525, Honolulu, HI 96813

²School of Electrical and Computer Engineering, Purdue University, 465 Northwestern Avenue, West Lafayette, IN 47907

³Department of Neurology: Division of Neuropsychology, University of Maryland School of Medicine, 110 S. Paca St. 3rd Floor, Baltimore, MD 21201

Abstract

Three Tribal Nations in the Pacific Northwest United States comprise the members of the CoASTAL cohort. These populations may be at risk for neurobehavioral impairment, i.e., amnesic shellfish poisoning, from shellfish consumption as a result of repeated, low-level domoic acid (DA) exposure present in local clams. Previous work with this cohort confirmed a high proportion of clam consumers with varying levels of potential exposure over time. Since clams are an episodically consumed food, traditional dietary records do not fully capture exposure. Frequency questionnaires can capture accumulated doses over time and this data can be used to examine dose-response relationships with periodic studies of memory and learning. However, frequency questionnaires cannot be used to assess consumption and memory response in real time. To address this shortcoming, a modified technology assisted dietary assessment (TADA) iPod application was developed to capture images of the clam meal, sourcing data, and associated memory functioning within 24 hours and seven days after consumption. This methodology was piloted with razor clam meals consumed by members from the CoASTAL cohort. Preliminary findings suggest that the TADA iPod application is potentially useful in collecting real-time data with respect to razor clam consumption, as well as one day and seven day memory outcome data. This technology holds promise for addressing the challenges of other HAB related dietary exposure outcome studies.

*Corresponding Author: Carol J Boushey, PhD, MPH, RD, Associate Professor, Epidemiology Program, University of Hawaii Cancer Center, 701 Ilalo Street, Room 525, Honolulu, HI 96813, United States, Tel: 808-564-5915, Fax: 808-586-2982, cjboushey@cc.hawaii.edu.

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Keywords

mobile technology; domoic acid; shellfish; razor clam; amnesic shellfish poisoning

1. Introduction

For more than 25 years, there has been a dramatic increase in the number of harmful algal blooms in coastal waters throughout the world (Anderson et al., 2012). As a result, there are more toxic algal species, more algal toxins, and more geographic regions encroached upon than formerly documented. When these toxic species proliferate, they may cause massive kills of fish and shellfish; wildlife mortality due to consumption at higher trophic levels; and human illness or death. One algal toxin, domoic acid (DA) is a known neurotoxin that has been associated with amnesic shellfish poisoning in humans (see Grattan et al. a,b, this issue). In the United States, *Pseudo-nitzschia*-producing blooms responsible for DA neurotoxins have been intermittently found in the coastal waters of the Pacific Northwest for nearly three decades (c.f. Trainer and Suddleson, 2005; Trainer et al., 2007). The primary mechanism for human exposure to DA is through razor clam consumption. Unlike other bivalve species, razor clams can harbor DA for an extended period of time due to their unique digestive system. As a result, exposures may occur after consuming fresh, frozen, or canned razor clam products for up to one year after harvesting. Protective measures are in place as shellfish harvesting beaches are closed when DA levels rise to 20 ppm. Although careful environmental monitoring and management has prevented outbreaks of Amnesic Shellfish poisoning in the region, the long-term impact of repeated, low-level exposure (less than 20 ppm) is less well-known. Since a human biomarker for exposure remains to be identified, a critical component of human health studies is the capacity to measure dietary exposure.

To facilitate the assessment of dietary exposure with respect to DA, the purpose of this brief report is twofold: 1) to summarize the current knowledge of razor clam consumption using traditional dietary assessment methods in a cohort of Native Americans at risk of DA exposure and 2) to introduce the adaptation of a novel measure to capture dietary intake using mobile technology.

2. Methods

2.1 Dietary Assessment of the CoASTAL Cohort

The CoASTAL cohort (Communities Advancing the Studies of Tribal Nations Across the Lifespan) represents members from three Pacific Northwest coastal Native American reservations. The cohort was assembled for the purpose of studying the impacts of repeated exposure to low levels of DA over time (Grattan et al., this issue, a, b; Tracy et al., this issue). In the absence of a human biomarker, robust dietary assessment is essential to studying the impact of long term exposure. To make the best use of available methods to capture dietary exposure, three dietary assessment methods were used to measure razor clam intake. This included the dietary record, a food frequency questionnaire (FFQ, Subar et al., 2001; Fialkowski et al 2010b, 2012), and the study-specific Shellfish Assessment Survey

(SAS, Fialkowski et al 2010a).a When Fialkowski and colleagues (2010a) compared the latter two methods; findings indicated that the SAS and the FFQ were similar in their ability to identify consumption levels in 518 adult participants. Specifically, the FFQ and SAS documented razor clam consumption rates in the cohort at 84% and 83% respectively over the course of one year (Fialkowski et al., 2010a). Although the FFQ has the capacity to assess a wider range of food and beverage consumption (including nutritional values), for the purpose of estimating relative exposures via shellfish intake, either measure could be used with reasonably good validity.

To determining relative exposure, both the FFQ and the SAS are based upon dietary recall for a time period immediately preceding assessment (e.g. 3 months, 6 months or one year). In contrast, dietary records are based upon detailed daily food diaries. This method is most useful when the objective is to measure absolute rather than relative intake; such as for comparisons with dietary recommendations (Dietary Reference Intakes, 2000). Detailed real-time recordkeeping of consumed food and beverages removes the error of generalizing population intake to that of individuals. In the previously described CoASTAL cohort sample (Fialkowski et al. 2010a; Tracy et al. this issue; Grattan et al. this issue), the proportion of individuals recording shellfish consumption over four days of dietary recordkeeping was 26%. Figure 1 shows the pattern of razor clam consumption from these dietary records. This relatively low consumption rate may be expected from these daily diaries records, compared to annual or seasonally based recall methods, as razor clams are an episodically consumed food (Tooze et al., 2006).

Capturing full penetration of a food product that is episodically eaten within a population is difficult to detect with only a few days of assessment. Increasing the amount of time participants are expected to complete daily written diaries is not typically useful due to loss of interest. Thus, this method is not useful on its own to assess exposure over time. Regardless of the dietary measure utilized to assess potential DA exposure and human neurotoxicity, linkages still need to be made with estimates of DA levels in the consumed clams (from sourcing data) and post-consumption memory ability (from standardized assessment). A mobile application was specifically developed for the CoASTAL cohort to collect all of this data with minimal participant burden in real-time..

2.1.1 Technologically Assisted Exposure Assessment—Since mobile phone use is ubiquitous to most people under the age of 65 (Pew Research Center, 2014) and taking pictures of food is a popular cell phone activity, CoASTAL cohort researchers examined ways to improve the accuracy of exposure and outcome assessment through mobile technology. Subsequently, the mobile food record (mFR) was modified and adapted for field use with the CoASTAL cohort. The application, running on the Technology Assisted Dietary Assessment (TADA) system for mobile device use, assessed dietary intake via participant captured images of food and beverages they were about to consume (Boushey et al., 2009; Zhu et al., 2010; Xu et al., 2012; He et al., 2013a; He et al., 2013b; Xu et al., 2013a; Xu et al., 2013b; Wang et al. 2015; Zhu et al., 2015). In addition to analyzing images of razor clam meals, the application was also designed to capture the source beaches for the consumed razor clams, and to collect real-time memory data.

Operationally, while the application runs on a mobile device, all data are sent to a central secure server, where investigators can view, analyze or download the data through a secure web application (Bosch et al., 2011; Ahmad et al., 2014). The TADA mFR system was modified to accommodate the situation of recording the food of interest i.e., razor clams, and identified as TADAd. Figures 2 through 5 illustrate the record screens throughout the data collection process. These include prompts for taking a photograph of a razor clam meal (Figure 2), a screen for documenting the source of the razor clams (Figure 3), a launch of and procedures for completing the memory questionnaire (Figure 4), and a mechanism for recording razor clam consumption that took place earlier in the day if the participant forgot to take a picture (Figure 5).

The small colored checkerboard square seen in the lower left of each button on the opening screens shown in Fig. 2 represents a fiducial marker (Xu et al., 2012). The fiducial marker is about 2-inches square. This item is included in every image as a color and size reference to help with the reconstruction of a three-dimensional environment that allows for estimation of the volume of the foods and beverages (Lee et al., 2012; Xu et al., 2012; Xu et al., 2013b). In this study, the food items were calibrated to represent a variety of razor clam preparations, including clam chowder.

In order to monitor potential alterations in memory, the Everyday Memory Questionnaire (Royle and Lincoln, 2008) was adapted and installed into the TADAd system. The memory questionnaire was launched 24 hours after a report of clam consumption and then again after 7 days. If an individual consumed clams several times a day or several times in the week, the launch sequence was set so that questionnaires would be separated by enough time to prevent user fatigue.

Since clams are not eaten every day, a mechanism was developed to remind participants to take images of clams to be consumed using methods of ecological momentary assessment (EMA) as a guide (Dunton et al., 2012; Marszalek et al., 2014). During random morning hours, users received a message asking, "Can you remember to send us throughout the day pictures of meals that include razor clams?" The question is accompanied by response buttons of "yes" or "no." If the user selects, "no," they are asked to type an explanation into a dialog box, e.g., "I have a dental appointment". At a random time toward the end of the day, users receive a second inquiry, "Did you eat any razor clams today, including mixtures containing razor clams (e.g., clam chowder, dip) and did not take a picture?" Again, the question is followed by a "yes" or "no" response request. If the user responds with "yes," the user is prompted with a short sequence of questions to record the clam eating occasion as shown in Figure 5.

The Apple iPod Touch 5th generation (with a rear facing camera) running on iOS6 was used for running the application. After receiving extensive training on the application, participants used the device for a 30 day time period, seasonally. Throughout the field testing process, participants were asked to complete a feedback questionnaire regarding the usability of the application. Inquiries targeted the ease of using the application and associated procedures and were adapted from other studies using the TADA system (Daugherty et al., 2012; Six et al., 2010). Preliminary findings suggest that the measure has good face validity and

participants were generally enthusiastic about using the application. It was considered easy to carry and the use of the fiducial marker was not burdensome. In some cases, the screens were thought to be difficult to read, but educating participants on how to adjust the brightness of the mobile screen or enlarge the font addressed this concern.

3. Discussion/Conclusion

The CoASTAL cohort is at risk of exposure to low levels of DA through razor clam consumption. Accordingly, the Food Frequency Questionnaire and the Shellfish Assessment Survey identified razor clam consumption rates of up to 84%. For more detailed dietary assessments that were less dependent upon memory recall, daily records were used. However, similar to other studies, the daily diaries did not fully capture razor clam intake in the cohort. To minimize the burden of daily dietary food records on participants, a well-validated mobile dietary record, the mFR, was adapted for use with the cohort. Operating within the TADAd application, information on the clams' source(s), as well as the individual's memory functioning, was also able to be assessed in real time. To maximize the research utility of this measure, initial and ongoing education for using this application is essential for participants and field teams. With further adaptations, this technologically assisted device could potentially be used to facilitate the assessment of dietary exposure and human health outcomes associated with other HAB-related illnesses.

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ABBREVIATIONS

DA	domoic acid
FFQ	food frequency questionnaire
mFR	mobile food record
SAS	Seafood Assessment Survey
TADA	Technology Assisted Dietary Assessment

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Fig. 1. Clam consumption from dietary records among members of the CoASTAL cohort by quarter from June 2005 – May 2008 (n=566). Average number of records per person is 5.3 ± 2.8 (range 1–11).

Fig. 2. The classic mobile food record (mFR) opening screen is on the left. The adaptation of the mFR for collecting a single food that is usually eaten in its entirety is the screen on the right.

Fig. 3.

The “Beach Location” screen is automatically displayed after an image is captured to allow the user to scroll through the list of 17 beaches plus an “unknown” choice to identify the clam source(s) by beach location. The user taps the beach name to select or deselect a beach. A check appears when a beach is selected (note: list shown is cut-off, the user scrolls through the list). Once finished, the user selects done and is returned to the opening screen.

Fig. 4.
Launching the memory questionnaire, questionnaire screens, and submit screen.

Fig. 5.

The sequence of screens above is launched when a user answers that s/he forgot to capture an image of an eating occasion which included clams. Once completed the responses are sent to the secure server.

Fig. 6.

A study participant's image of razor clam fritters as viewed on the web application. The GPS coordinates listed under the image name have been redacted.