Dietary Assessment – moving from paper to the digital domain

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Epidemiology Program
University of Hawaii Cancer Center
Outline

• Application to the Nutrition Care Process
• Introduction to image analysis
• Validation studies - results of first phase studies
• Survey of methods under development
• Tips for considering use of mobile devices
Nutrition Care Process & Model

The Nutrition Care Process and Model

Nutrition Assessment & Re-assessment
- Obtain/collect timely & appropriate data
- Analyze/interpret with evidence-based standards
- Document

Nutrition Diagnosis
- Identify & label problem
- Determine cause/contributing risk factors
- Cluster signs & symptoms/defining characteristics
- Document

Nutrition Intervention
- Plan nutrition intervention
- Formulate goals & determine a plan of action
- Implement nutrition intervention
- Care is delivered & actions are carried out
- Document

Nutrition Monitoring & Evaluation
- Monitor progress
- Measure outcome indicators
- Evaluate outcomes
- Document

Outcomes Management System
- Monitor the success of the Nutrition Care Process implementation
- Evaluate the impact with aggregate data
- Identify and analyze causes of less than optimal performance and outcomes
- Refine the use of the Nutrition Care Process

Source: http://www.eatright.org
NCP Steps

1. Nutrition Assessment
2. Nutrition Diagnosis
   - PES statement
   - Problem, Etiology, Signs/Symptoms
   - Consider the intake domain as the preferred problem
3. Nutrition Intervention
4. Nutrition Monitoring and Evaluation
<table>
<thead>
<tr>
<th>Assessment</th>
<th>Food/Nutrition History</th>
<th>Biochemical Data, Medical Tests, and Procedures</th>
<th>Anthropometric Measurements</th>
<th>Physical Examination Findings</th>
<th>Client History</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Food and nutrient intake, nutrition related knowledge and practices, etc.</td>
<td>Laboratory data (e.g., glucose) and tests (e.g., REE), etc.</td>
<td>Height, weight, rate of weight change, etc.</td>
<td>Oral health, physical appearance, etc.</td>
<td>Medication use, medical / health history, etc.</td>
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### Diagnosis

<table>
<thead>
<tr>
<th>Intake</th>
<th>Clinical</th>
<th>Behavioral-Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too much or too little of a food or nutrient compared to actual of estimated needs.</td>
<td>Nutrition problems that relate to medical or physical conditions.</td>
<td>Knowledge, attitudes, beliefs, physical environment, access to food, or food safety.</td>
</tr>
</tbody>
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### Intervention

<table>
<thead>
<tr>
<th>Food and/or Nutrient Delivery</th>
<th>Nutrition Education</th>
<th>Nutrition Counseling</th>
<th>Coordination of Nutrition Care</th>
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<tbody>
<tr>
<td>An individualized approach for food / nutrient provision, including meals and snacks…</td>
<td>A formal process to instruct or train…or modify food choices and eating behavior…</td>
<td>A supportive process…create individualized action plans…</td>
<td>Consultation with, referral to…that can assist in treating or managing …problems</td>
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### Monitoring & Evaluation

<table>
<thead>
<tr>
<th>Nutrition-related Behavioral and Environmental Outcomes</th>
<th>Food and Nutrient Intake Outcomes</th>
<th>Nutrition-Related Physical Sign and Symptom Outcomes</th>
<th>Nutrition-Related Patient/Client-Centered Outcomes</th>
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<tbody>
<tr>
<td>Nutrition-related knowledge…impact food and nutrient intake.</td>
<td>Food and/or nutrient intake from all sources.</td>
<td>Anthropometric, biochemical, and physical …indices.</td>
<td>Perception of patient/client’s nutrition intervention…</td>
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**NCP Snapshot**

Source: eatright.org
### Assessment

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**NCP Snapshot**

Source: eatright.org
Nutrition Assessment Matrix

- Food/Nutrition-Related Nutrition Diagnostic Terminology
  - 31 parameters
  - Food & Nutrient Intake (one of the parameters)
  - Nutrition Diagnostic Terminology (NDT)
    - e.g., NI 1.5. Excess intake of energy…
  - A total of 53 NDTs for Food & Nutrient Intake
Issues with paper-based methods?

- Burden on the client
- Analysis time for the practitioner
- Measurement error
There must be a better way…

• Dietary assessment among adolescents is problematic

• Ages 11-14 years is particularly challenging
  – Novelty of recording food has worn off
  – Assistance from parents is no longer welcome

“Go home and take pictures of the food you eat”

30 boys & girls
10 - 14 y
Sample images
Before and after
## Cooperation using camera

<table>
<thead>
<tr>
<th>Camera food record kept for:</th>
<th>0 day</th>
<th>1 day as requested</th>
<th>2 days, more than requested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of children (n=30)</td>
<td>1</td>
<td>6</td>
<td>23</td>
</tr>
</tbody>
</table>

Responses as % about preferences for dietary assessment methods (n=29)

<table>
<thead>
<tr>
<th>Response to “I liked…”</th>
<th>Food record</th>
<th>24 hr recall</th>
<th>PDA tree</th>
<th>PDA search</th>
<th>Camera</th>
<th>PDA camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agree</td>
<td>35</td>
<td>52</td>
<td>38</td>
<td>75</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Neutral</td>
<td>31</td>
<td>21</td>
<td>34</td>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Disagree</td>
<td>35</td>
<td>28</td>
<td>28</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Study Design

#### 24-hour schedule

<table>
<thead>
<tr>
<th>Time</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 am</td>
<td>Breakfast</td>
<td>8:00 am</td>
</tr>
<tr>
<td></td>
<td>Pick up</td>
<td>Return home</td>
</tr>
<tr>
<td></td>
<td>Breakfast</td>
<td>7 SNACKS</td>
</tr>
<tr>
<td></td>
<td>Lunch</td>
<td>7 SNACKS</td>
</tr>
<tr>
<td></td>
<td>Dinner</td>
<td>8 SNACKS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 SNACKS</td>
</tr>
</tbody>
</table>

19 Unique foods served
- Cheeseburger Sandwich
- Chocolate Cake, Iced
- Coke
- Eggs, Scrambled
- French Dressing
- French Fries
- Garlic Bread, toasted
- Lettuce, romaine mix
- Margarine
- Milk, 2%
- Orange Juice
- Peach, canned slices
- Pear, canned halves
- Sausage Links
- Spaghetti with Sauce, Cheese
- Strawberry Jam
- Sugar Cookie
- Tomato Catsup
- White Toast

Total 330 foods

Six et al. J Am Diet Assoc 2010
• Training images – groundtruth images
• Segmentation – interactive version and automatic version using Normalized Cut
• Features – color, texture, shape, SIFT
• Classification – Bag of Features and SVM
24hr Database – Breakfast

Zhu et al. IEEE Journal of Selected Topics in Signal Processing, 2010
24hr Database – Lunch

Ground Truth

Automatic

Zhu et al. IEEE Journal of Selected Topics in Signal Processing, 2010
24hr Database – Dinner

Ground Truth

Automatic

Zhu et al. IEEE Journal of Selected Topics in Signal Processing, 2010
## Classification Accuracy of Food Items

<table>
<thead>
<tr>
<th>Percentage of Training Data</th>
<th>Correct Classification Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>88.1</td>
</tr>
<tr>
<td>25</td>
<td>94.4</td>
</tr>
<tr>
<td>50</td>
<td>97.2</td>
</tr>
</tbody>
</table>

| Scrambled eggs - 10% training | 70% | 30% (Margarine) |
| Scrambled eggs - 25% training | 78% | 22% (Margarine) |
| Scrambled eggs - 50% training | 87% | 13% (Margarine) |

Zhu et al. IEEE Journal of Selected Topics in Signal Processing, 2010
Volume Estimation
Food Volume Estimation

Example

Input datasets
- Meal image
- Segmented images

Results
- Best-fit shape templates
  - Geometrical class: Cylindrical shape
  - Geometrical class: Box shape
- Extracted feature points
- Estimated volumes

Food Code
- 11112110 (Milk)
- 53105500 (Chocolate cake)

Woo et al. Electrical Imaging Science and Technology, 2010
### Food Items

1. Sausage Links
2. Spaghetti w/ sauce, cheese
3. French dressing
4. Milk, 2%
5. Cheeseburger sandwich
6. Strawberry jam
7. Orange juice
8. Ketchup
9. Sugar cookie
10. Chocolate cake w/ icing
11. Coke
12. Margarine
13. Toast
14. Sliced peaches
15. Scrambled eggs
16. Pear halves
17. French fries
18. Garlic bread
19. Lettuce salad

---

**Weight and energy error using volume image analysis by food from images taken by 15 adolescents (11-18 y) over a 24-hour period**

![Graph showing weight and energy error](Image)
Color Fiducial Marker

Reference Illumination

New Illumination #1

New Illumination #2

Color Correction

Xu et al. Proceedings IS&T/SPIE, 2012
CELL PHONE TIMELINE

1992: Motorola MicroTac
1994: Motorola StarTac
1996: Nokia 1610
1997: Qualcomm QCP2700
1999: Ericsson A1228d

2000: Palm Treo 600
2001: Motorola V60c
2002: Sony Ericsson T616
2003: Motorola RAZRv3
2004: Sony Ericsson W810i
2005: Sony Ericsson W820i

2006: AT&T 8525
2007: AT&T 8925
2008: Blackberry 8830
2008: BlackBerry Bold 9700
2010: Apple iPhone 3G
Today: Apple iPhone 5

http://2.bp.blogspot.com/_gUcx9TAR2H8/TRS0DJ7NgMI/AAAAAAAAAi0/XJLgVUFip54/s1600/cellphone_timeline.jpg
mHealth: health care delivery and treatment

- In the U.S.
  - Adolescents
    - 75% have a mobile telephone
    - 50% get first telephone at 12-13 yrs.
  - Adults
    - 85% have a mobile telephone
    - 35% have a smartphone

- ~ 5 billion mobile subscribers worldwide
  - 2/3 are in developing countries
- ~90% of the world has wireless network

http://www.pewinternet.org/topics/Mobile.aspx
## Digital Entry Dietary Records

iPhone: >1200 apps
Average price: $2.39

### Growth of health apps by platform over six month period

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>4276</td>
<td>2860</td>
<td>7136</td>
<td>↑ 67</td>
</tr>
<tr>
<td>Google Android</td>
<td>505</td>
<td>791</td>
<td>1296</td>
<td>↑ 157</td>
</tr>
<tr>
<td>BlackBerry</td>
<td>140</td>
<td>198</td>
<td>338</td>
<td>↑ 141</td>
</tr>
</tbody>
</table>

mobihealthnews. 2010 report.
Fig. 1. Screen capture of the food diary entry page of My Meal Mate. (A colour version of this figure can be found online at www.journals.cambridge.org/bjn)

Fig. 2. Screen capture of the search page for finding a food to add to the diary. (A colour version of this figure can be found online at www.journals.cambridge.org/bjn)

Carter MC et al, Brit J Nutr 2013
# Image-based dietary assessment

<table>
<thead>
<tr>
<th>Sample of methods in development</th>
<th>Focus of process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote Food Photography Method</td>
<td>Trained Analyst</td>
</tr>
<tr>
<td>Martin CK et al Brit J Nutr 2009</td>
<td></td>
</tr>
<tr>
<td>A Unified Sensor System</td>
<td>Participant</td>
</tr>
<tr>
<td>Sun M et al J Am Diet Assoc. 2010</td>
<td></td>
</tr>
<tr>
<td>Image Diet Day</td>
<td>Automation w/ some user confirmation</td>
</tr>
<tr>
<td>Arab L and Winter A J Am Diet Assoc. 2010</td>
<td></td>
</tr>
<tr>
<td>Food Intake Visualization &amp; Voice Recognizer</td>
<td></td>
</tr>
<tr>
<td>Weiss R et al J Am Diet Assoc. 2010</td>
<td></td>
</tr>
<tr>
<td>Mobile telephone food record (mpFR)</td>
<td></td>
</tr>
<tr>
<td>Boushey CJ et al Euro J Clin Nutr 2009</td>
<td></td>
</tr>
<tr>
<td>Diet Data Recorder System (DDRS)</td>
<td></td>
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</table>
Rubrics for image-assisted records or recalls

- Image-assisted
  - Non-automated
    - Analysts
      - Portion Size
      - Food Identification
  - Automated
    - Portion Size
    - Food Identification
      - Supplemented with analyst or respondent

Mobile Telephone Food Record (mpFR) System

Image(s) + Metadata
(Geolocation, Time, Barcode, Contextual Info)

Client

1

Server

2

3

Volume Estimation

Communication Layer

Web Server

TADA Databases

I-TADA

T-FNDDS

E-TADA

4

Review

- Labeled Images With Food Type (e.g., Milk, Toast, Eggs)

5

User Confirmation

Wi-Fi/3G/4G Network

6

Research community

Internet

mpFR Instructions

1. ALL food and beverages
2. Fiducial Marker

Six et al, J Am Diet Assoc. 2010
• Mobile Telephone Food Record (mpFR)
  ▪ Record Eating Events
    ▪ Capture a series of before/after image pairs
    ▪ Barcode reader
  ▪ Review Meal
    ▪ Review food items in images
    ▪ Confirm and adjust food identification
    ▪ Barcode Reader
  ▪ Alternative Method
    ▪ Manage eating events when food images are not captured
Mobile Food Intake Visualization and Voice Recognizer (FIVR)

PI: Rick Weiss, Viocare, Inc.

- User captures food records using video/images & voice using a mobile phone
- FIVR automatically identifies foods and portion sizes to reduce participant burden
- 3D structure analysis used to calculate volume/portion size from images of multiple angles
- Image recognition is used to match foods to library of foods using color, texture, shape
- FIVR calculates nutrient and food intake of consumed food
eButton for Diet and Physical Activity Assessment
PI: Mingui Sun, University of Pittsburgh

Concept: Subject wears an eButton which has an array of sensors to collect food and physical activity data every 2-4 seconds. The data are then uploaded and analyzed for energy intake and expenditure.

The plate diameter is used as a size reference. Food volume is measured using a wire mesh.

Image features and GPS/motion data are used for automatic physical activity recognition.
Text messaging intervention group participants receive ongoing motivational messages.

Text Message sent to participant

Mobile Friendly Web page

Hi Kate, it’s Amelia from CHAT with your junk food score. You averaged 5 serves a day, varying from 1-11 serves over 4 days. Junk foods are fatty, salty or sugary foods that are high in calories. Try to only eat these foods sometimes and if you do, in small amounts. Click here to see what a junk food serve looks like


What is a serve?

So what is junk food? Junk food is fatty, salty or sugary foods that are usually high in calories. Try eating these foods only sometimes and if you do, in small amounts.

**A serve of junk food = around 140 calories (or 600 kilojoules) per serve.**

Junk Food Serves

- 1/2 cup of chips
- 1/2 cup of cooked pasta
- 1 medium sized potato
- 1/2 medium sized fruit
- 1 large egg
- 1 cup of rice or pasta
- 1/3 of a can of evaporated milk
- 1/4 of a can of melted butter
Text messaging intervention group participants receive ongoing motivational messages.

Text Message sent to participant:

Veggies can taste great if you know how to cook them. Try a quick and easy stir fry.

Click on link in text:

Mobile Friendly Web page:

Beef, Broccoli & Snow Pea Stir-Fry

15 Mins prep, 10 Mins Cooking
$15 - feeds 5 people & is 1 serve of veg each!

Slice it! Cook it! Take it out!

Heat up the Oil!

Combine these!

- 2 tbsp Oil
- 400g Rump Steak
- 1/2 tbsp Oyster Sauce
- 2 tbsp Water
- 1 tbsp Chilli Sauce
- 1/2 tbsp Reduced-salt Soy Sauce

In here!

Chop into tree's

Chop off the ends!

Sleing it! Dice it!

2 Garlic Cloves
1/2 head of Broccoli
100g Snow Peas
1/2 tsp Ginger

Cook the veg!

Cook them like the packet says!

Mix everything together in the wok!

250g Hokkien Egg Noodles

Make it hot!

Eat it!
Tips for using mobile devices in research/practice

- Theoretical frameworks
Evaluation model for mobile applications

Usability
- learnability,
- efficiency of use, errors
- and satisfaction

Utility
- adherence, persistence,
- attrition

Features
- social components, expert
- feedback, reminders,
- educational content

Adoption
- acceptance, preference

Outcomes
- weight loss metrics,
- behavioral change,
- improved dietary assessment

Adapted from Dohan et al. AISeL 2011
Data collection

Theoretical framework:
The tailored intervention will be based on self-determination theory and informed by motivational interviewing.

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<th>Substitutions</th>
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<td><strong>Switching to</strong></td>
</tr>
<tr>
<td>Servings of fruit and/or vegetables</td>
<td>Low energy/diet drinks or waters</td>
</tr>
<tr>
<td>Variety of fruits and vegetables</td>
<td>Lower-alcohol or non-alcoholic drinks</td>
</tr>
<tr>
<td>Adding more vegetables or salad to meals</td>
<td>Healthier options when eating out</td>
</tr>
<tr>
<td></td>
<td>More alcohol free days every week</td>
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<table>
<thead>
<tr>
<th><strong>Ate/drank less:</strong></th>
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<td>Sugary drinks (e.g. fizzy drinks, sports drinks or cordial)</td>
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<tr>
<td>Confectionary (e.g. chocolate, lollies, cakes, sweet biscuits)</td>
</tr>
<tr>
<td>Sugary foods (e.g. lollies, sugar in drinks)</td>
</tr>
<tr>
<td>Fatty foods (e.g. pies, pastries)</td>
</tr>
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<td>Alcohol</td>
</tr>
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<td>Fast food</td>
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Tips for using mobile devices in research/practice

- Theoretical frameworks
- Collaborate with an electrical and/or computer engineer
Tips for using mobile devices in research/practice

- Theoretical frameworks
- Collaborate with an electrical and/or computer engineer
- Learn and use terminology
## Examples of terminology

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<th>Professional Term</th>
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<tr>
<td>Photo or photograph</td>
<td>Image or digital image (or even picture)</td>
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<td>Capture an image, take an image (or even take a picture)</td>
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<tr>
<td>Cell phone</td>
<td>Mobile telephone</td>
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<td>WiFi, Bluetooth</td>
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Tips for using mobile devices in research/practice

- Theoretical frameworks
- Collaborate with an electrical and/or computer engineer
- Learn and use terminology
- Cost & mechanics
## Cost & Mechanics

### Mobile telephone

- **Data service plans**
  - Purchase phones
  - **Device cost**
  - Monthly voice cost
  - Data cost
  - Text cost

<table>
<thead>
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<th>Device cost</th>
<th>Monthly voice cost</th>
<th>Data cost</th>
<th>Text cost</th>
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<tr>
<td>$275/device</td>
<td>$25/protectors</td>
<td>$300 total/device</td>
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- Distribute and return, or
- Give telephone to participants

### Mobile devices, such as an Apple iPod

- No service plan
- **Device cost**
  - $275/device +
  - $25/protectors =
  - $300 total/device

---

*Note: $41.49/phone + $5.00/phone*
Many Thanks

PI: Carol Boushey, PhD, MPH, RD
At Purdue University
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Deb Kerr, PhD

Department of Agricultural & Biological Engineering
Martin Okos, PhD
Shivangi Kelkar
Scott Stella

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David Ebert, PhD
Nitin Khanna, PhD
Marc Bosch
Junghoon Chae
Ye He
Fengqing Zhu
Xu Chang
Ziad Ahmad

[Image]