Dietary intake assessment using technology including wearables: gaps and requirements

ILSI N America, Session 1
Janet Cade
Janet Cade is Director of University of Leeds spin out company Dietary Assessment Ltd – supporting myfood24.

Research funding on dietary assessment received from:
- UK Medical Research Council
- Innovate UK
What will I be covering?

- Challenges of measuring diet
- Online, apps & wearables
- New forms of data
- Improving standards
'.... reports have asserted that, because of energy underreporting, dietary self-report data suffer from measurement error so great that findings that rely on them are of no value.' Subar et al, J Nutr 2015;145:2639–45.

‘In lieu of measuring actual dietary intake, epidemiologists collected millions of unverified verbal and textual reports of memories of perceptions of dietary intake.’
Why do we need to improve?

- can’t adequately answer research questions!

Reducing measurement error  
Improve accuracy of usual dietary intake assessment  
Strengthen associations between diet & disease
New methods relevant to dietary assessment?

• Online tools, apps, cameras

Wearables - sensors (fitbits etc)

Twitter, social media

Census/survey
Geolocation, town planning data

Metabolomics, biomarkers
Healthcare data – 1º care & 2º care
Development of dietary intake assessment tools 2000-2018

Eldridge, 2018
We are crossing the technology divide, but we aren’t there yet…

Eldridge, 2018
ILSI Review:

Keywords searches from Jan 2011-Sept 2017; English language articles

4695 Articles Identified

- PubMed, PLOS, BioMed, Science Direct, OVID

800 Articles Screened

- Removed duplicates and irrelevant articles (n=3895)

85 Tools Identified

- Exclusions (n=42)

43 Tools Evaluated
We identified three main types of tools

15 Smartphone apps

2 Wearables:
- eButton
- MS SenseCam

26 PC or web-based tools

Plus, app/wearable combinations:
- FoodNow, Australia – wearable armband for energy expenditure.
- Diabetics Diary, Norway – android smartphone paired with Pebble smartwatch
Main challenges for new technologies:

1. Data entry
2. Food identification (what is it?)
3. Food description (details)
4. Food composition (databases)
5. Nutrient and food outputs
6. Lack of customisation
7. Lack of validation
1. Data entry

79% of tools relied on **self-report, self-entry**

91% used text entry & 33% used **digital images** to *help* identify foods

- Integrated tools for diet and health still lacking
Data entry innovation: photography

- Most semi-automatic, still need text
- Fiducial marker needed
- Before and after photo
- Angles important
- Challenges with recipe dishes – segmentation needed
- Smartphone or wearable
2. Food identification

Nearly all (91%) relied on **manual identification** of foods. Only 65% had integrated databases for estimating energy or nutrients.
3. Food description

Innovations: food image identification technologies are improving, as are quantity estimations – BUT cannot replace some self-entry or checking.

Most challenging to estimate volume from 2D image without depth information.
Novel classification strategies for image recognition

- Traditional machine learning using handcrafted features.
- Visual features extracted from food image, used to train prediction model.
- Deep learning-based approach.
- A large number of connected layers can learn features (e.g., colour, texture, shape), final layer for classification.
Different styles available:

- Most use national databases - limited
- European food classification – FoodEx2 complex
- Brand level details – crowd sourcing potential missing data
### Innacurate databases – missing values

Franco et al. JMIR Mhealth Uhealth 2016;4(3):e85

<table>
<thead>
<tr>
<th>App name</th>
<th>Abbreviation</th>
<th>Installs (range), n</th>
<th>Reviews, n</th>
<th>Rating (0-5)</th>
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<tbody>
<tr>
<td>S Health-Fitness Diet Tracker</td>
<td>SH</td>
<td>100m-500m</td>
<td>33,619</td>
<td>3.7</td>
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<tr>
<td>Calorie Counter-MyFitnessPal</td>
<td>MFP</td>
<td>10m-50m</td>
<td>1,140,897</td>
<td>4.6</td>
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<tr>
<td>Calorie Counter by FatSecret</td>
<td>FS</td>
<td>10m-50m</td>
<td>178,438</td>
<td>4.3</td>
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<tr>
<td>Noom Coach: Weight Loss Plan</td>
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<td>My Diet Coach-Weight Loss b</td>
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<td>Lose it! by FitNow Inc</td>
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<td>Weight Watchers Mobile c</td>
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<td>Lose Weight Without Dieting</td>
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<td>Lifesum-The Health Movement</td>
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<td>Diet Point-Weight Loss by Diet Point d</td>
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#### Nutrition Facts

**Walnuts - Tablespoon**

- **Calories**: 76
- **Total Fat**: 5 g
- **Saturated Fat**: 3 g
- **Polyunsaturated Fat**: 1 g
- **Monounsaturated Fat**: 1 g
- **Cholesterol**: 15 mg
- **Sodium**: 41 mg
- **Total Carbs**: 1 g
- **Dietary Fiber**: 0 g
- **Total Sugars**: 0 g
- **Protein**: 1 g

**Larkburger - Parmesan Truffle Fries**

- **Calories**: 422
- **Total Fat**: 22 g
- **Saturated Fat**: 0 g
- **Polyunsaturated Fat**: 0 g
- **Monounsaturated Fat**: 0 g
- **Cholesterol**: 0 mg
- **Sodium**: 0 mg
- **Total Carbs**: 49 g
- **Dietary Fiber**: 0 g
- **Total Sugars**: 0 g
- **Protein**: 10 g
- **Cholesterol**: 0 mg

*Percent Daily Values are based on a 2000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.
Database development - brands

~45,000 items
8 nutrients

3,500 items
120 nutrients

Mapped on energy, fat, protein, & carbohydrate

Over 50% within 10% agreement for energy

Largest food groups mapped:
- cakes, biscuits, etc (6918 items, 18%);
- alcoholic drinks (5692 items, 15%);
- sauces & condiments (3635 items, 9%).

Carter et al, Nutrients, 8 (8) doi 10.3390/nu8080480
5. Outputs - limited

Most reported energy (65%) and macronutrients (70%), but fewer reported micronutrients (53%) and food groups (67%)

Only 53% generated automatic reports
Nutrient data from apps - unreliable
Chen et al, JMIR mHealth uHealth 2015;3(4):e104

App v. 3 day diary:

Difference in energy intake estimates

- Calorie Counter by FatSecret
- Calorie Counter Pro My Net Diary
- Food Diary and Calorie Tracker
- My Diet Diary Calorie Counter
- Value Diary Plus
- Noom Weight Loss Coach
- Jillian Michaels Slim-Down
- Diet Watchers Diary
- Easy Diet Diary
- Control my weight
- Calorie Counter & Diet Tracker
- My Diet Coach Pro
- MyPlate Calorie Tracker LITE
- Nutritionist – dieting made easy
- Map My’ + apps (walk, run, ride, fitness)
- Map My’ apps (walk, run, ride, fitness)
- Calorie Counter by Sparkpeople
- Cronometer
- Calorie Counter - MyFitnessPal
- Body tracker – body fat tracker
- Pts plus weight diary
- Points calculator and weekly weight loss
- Point tracker weight watchers
- My Diet Diary Calorie Counter
- Calorie Counter & Diet Tracker
- My Diet Coach Pro
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Mean (95% CI)

Energy difference (kJ)

<table>
<thead>
<tr>
<th>App</th>
<th>Energy Difference (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorie Counter by FatSecret</td>
<td>-39</td>
</tr>
<tr>
<td>Calorie Counter Pro My Net Diary</td>
<td>-39</td>
</tr>
<tr>
<td>Food Diary and Calorie Tracker</td>
<td>-114</td>
</tr>
<tr>
<td>My Diet Diary Calorie Counter</td>
<td>-300</td>
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<tr>
<td>Value Diary Plus</td>
<td>-846</td>
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<tr>
<td>Noom Weight Loss Coach</td>
<td>-963</td>
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<tr>
<td>Jillian Michaels Slim-Down</td>
<td>-985</td>
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<tr>
<td>Diet Watchers Diary</td>
<td>-956</td>
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<tr>
<td>Easy Diet Diary</td>
<td>-943</td>
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<tr>
<td>Control my weight</td>
<td>-824</td>
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<tr>
<td>Calorie Counter &amp; Diet Tracker</td>
<td>-663</td>
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<tr>
<td>My Diet Coach Pro</td>
<td>-483</td>
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<tr>
<td>MyPlate Calorie Tracker LITE</td>
<td>-396</td>
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<tr>
<td>Nutritionist – dieting made easy</td>
<td>-254</td>
</tr>
<tr>
<td>Map My’ + apps (walk, run, ride, fitness)</td>
<td>-104</td>
</tr>
<tr>
<td>Map My’ apps (walk, run, ride, fitness)</td>
<td>-127</td>
</tr>
</tbody>
</table>
6. Customization

Less than half reported any features of customization, like missing foods, recipes or use of dietary supplements.
7. Validity required

Improvement needed in validation methods and reporting:
only 6 studies compared intakes to DLW or biomarkers

Usability: influences compliance; time to complete varies widely depending on purpose of tool
Validated online dietary assessment

myfood24 – a new tool for researchers, teachers & clinicians. UK, German, Danish versions. Other languages and databases possible.
Validation study results:

- Biomarkers from 212 participants
- myfood24 *similar results* to more costly & time consuming interviewer-based MPR
- median total E intake: men 2044 kcal (NDNS 2107 kcal).
- median women: 1613kcal (NDNS 1595kcal)
- Both dietary assessment approaches led to attenuation compared to biomarkers
Wearable device trackers increasing

Forecast Unit Shipments for Wearable Devices

CCS Insight: Wearables Market to Be Worth $25 Billion by 2019

Statista 2018
Wearable sensors to monitor eating habits

Could measure:

• Timing of eating
• Duration and microstructure of food intake episodes
• Rate of ingestion
• Ingested mass
• Nutrient and energy intakes?

Hassannejad et al, INTERNATIONAL JOURNAL OF FOOD SCIENCES AND NUTRITION, 2017 VOL. 68, NO. 6, 656–670
In development........
Wearable monitors – energy expenditure

- 3 multisensory monitors
- 1 accelerometry only (Jawbone)

Compared to research grade devices.

- Consumer wearables not yet equivalent to best research devices.
- All have negative bias.

Chowdhury et al. PLOS ONE
DOI:10.1371/journal.pone.0171720 February 24, 2017
Wearable oral electronics

A thin breathable membrane in the mouth to measure salt intake. Designed for people with hypertension etc.

Lee et al. PNAS | May 22, 2018 | vol. 115 | no. 21 | 5377–5382

Tufts implant – tracks glucose, salt, alcohol

A wearable intake monitor providing number of bites can reduce overall intake in one meal. Bites ‘roughly’ correlate with calories.

Jasper et al, J Acad Nutr Diet, 2016; 116: 1785-93

CAVEAT: sensors need testing in field tests not laboratory (Doulah, IEEE, 2018).

Lab experiments did not reflect real life behaviour for meal microstructure eg. number of bites, chewing, duration, bite size, rate of amount consumed etc.
New forms of data

Big Data Is More Than 3 Vs*

*2001 (Meta) / 2012 (Gartner) Definition of Big Data

**Volume**
- IDC Report 2011
  - 8 billion TB in 2015
  - 40 billion TB in 2020
  - 90% of all data < 2 years
  - storage • transport • processing

**Variety**
- relational, graph time series, sensor, audio, video, text, geo, scientific, ...
- 80% unstructured

**Velocity**
- facebook 500 TB/day
- Large Hadron 35 Gb/sec
twitter 300K tweets/min
- real time • stream
Priorities for action:
big data for food monitoring research

- Eliminate handwritten data (digitise)
- Invest in IT systems, including analysts
- Develop better predictive analyses
- Move from retrospective troubleshooting to problem prevention
- Use structured and unstructured data
- Develop public-private partnerships
- Develop strategies to ensure data quality

Which tool is right for me?
Introducing Nutritools.org

Supports dietary assessment through guidance and access to validated dietary assessment tools.

For use in research and teaching.

Includes food questionnaire creator.
Showing 10 validated USA dietary assessment tools included (total 127 tools world-wide)

<table>
<thead>
<tr>
<th>Tool Library</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Validation Method Filter</strong></td>
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<tr>
<td><em>Save</em></td>
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<tr>
<td><strong>Lifestyle</strong></td>
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<tr>
<td>Infant and toddlers</td>
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<tr>
<td>Children</td>
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<td>Adolescents</td>
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<td>Adults</td>
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<td>Elderly</td>
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<tr>
<td><strong>Comparator</strong></td>
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<tr>
<td>Weighed Food Diary</td>
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<td>Food Diary Estimated</td>
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<td>Food Checklist</td>
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<tr>
<td>Diet Histories</td>
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<tr>
<td>Food Frequency Questionnaire</td>
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<tr>
<td>Biomarkers</td>
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<tr>
<td>County Labelled Water</td>
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<tr>
<td>Other</td>
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<tr>
<td><strong>Year of Tool Validation</strong></td>
</tr>
<tr>
<td>1990-95</td>
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<td>1990-00</td>
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<td>2010-至今</td>
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<td><strong>Area</strong></td>
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<td>UK</td>
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<td>Europe (excluding UK)</td>
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<td>North America</td>
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<td>South America</td>
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<td>Asia</td>
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<td>Africa</td>
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<tr>
<td>Oceania</td>
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</table>

Below is a list of all the identified and validated Tools. Scroll through and select a Tool to display more information.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Description</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>🇨🇦 24h Recall (Web-SPAN)</td>
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<td>Storey</td>
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<tr>
<td>🇨🇦 AMPM</td>
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<td>Blanton</td>
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<tr>
<td>🇨🇦 ASA24</td>
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<td>Subar</td>
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<tr>
<td>🇨🇦 ASA24-Kids</td>
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<td>Baranowski</td>
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<tr>
<td>🇨🇦 COMPASS questionnaire</td>
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<td>Leatherdale</td>
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<tr>
<td>🇨🇦 FFQ (Inuvialuit)</td>
<td></td>
<td>Sharma</td>
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<tr>
<td>🇨🇦 FFQ (Pregnant Women)</td>
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<td>Mejía-Rodríguez</td>
</tr>
<tr>
<td>🇨🇦 Multiple Pass 24h Recall</td>
<td></td>
<td>Johnson</td>
</tr>
<tr>
<td>🇨🇦 Remote Food Photography Method (RFPM)</td>
<td></td>
<td>Martin</td>
</tr>
<tr>
<td>🇨🇦 School-Based Nutrition Monitoring (SBNM) questionnaire</td>
<td></td>
<td>Hoelscher</td>
</tr>
</tbody>
</table>

10 Tools displayed out of a possible 127 Tools.
Tool Visualisation – bubble & summary plots

Bubble colours represent different DATs

Each bubble is a validation study.

The size of each bubble represents the sample size in each validation study.

Arrows indicate the limits of agreement. (the variation across the differences)

The summary plots are a visual approach to compare the mean difference in intakes for certain nutrients between the dietary assessment tools and the comparators used in the validation studies.

X variable: Zinc (mg)

Difference between DAT and reference method

The arrows represent the upper and lower limits of agreement and the size of the bubble equates to the sample size.

Click on the bubble or arrows to display summary information including the lifestage of the population validated, the comparator used and the specific data points of the mean difference and limits of agreement which are needed to compare the assessment tools.

Not all validation papers are included in the graph and some of the data points are median differences, click on the bubbles to find out.

Some results have been calculated using statistical techniques based on the published data. To find more information read the validation article.
Summary

• Measuring food and nutrient intakes in populations is difficult.

• Methods limit ability to link diet to health – including inadequate food tables & lack of portion information.

• Use of well designed and tested tools, including wearables, could help.

➢ Potential for a step-change in ability to reliably characterise food and nutrient intake in population studies

“Is it better to be roughly right with small data than precisely wrong with big data?” (Greenwood)