RESEARCH
Review

Image-Assisted Dietary Assessment: A Systematic Review of the Evidence

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ABSTRACT
Images captured during eating episodes provide objective information to assist in the assessment of dietary intake. Images are captured using handheld devices or wearable cameras, and can support traditional self-report or provide the primary record of dietary intake. A diverse range of image-assisted methods have been developed and evaluated but have not been previously examined together. Therefore, a review was undertaken to examine all studies that have evaluated or validated image-assisted methods of dietary assessment for assessing dietary energy intake. Identified image-assisted methods that employ similar methodologies were grouped for comparison. English-language full-text research articles published between January 1998 and November 2013 were searched using five electronic databases. A search of reference lists and associated websites was also conducted. Thirteen studies that evaluated 10 unique image-assisted methods among adults aged 18 to 70 years were included. Ten studies used handheld devices and three studies used wearable cameras. Eight studies evaluated image-based food records, two studies explored the use of images to enhance written food records, and three studies evaluated image-assisted 24-hour dietary recalls. Results indicate images enhance self-report by revealing unreported foods and identify misreporting errors not captured by traditional methods alone. Moreover, when used as the primary record of dietary intake, images can provide valid estimates of energy intake. However, image-assisted methods that rely on image analysis can be prone to underestimation if users do not capture images of satisfactory quality before all foods are consumed. Further validation studies using criterion measures are warranted. The validity among children, adolescents, and elderly persons as well as the feasibility of using image-assisted methods in large samples needs to be examined. Additional research is also needed to better understand the potential applications and pitfalls of wearable cameras.
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THERE IS A CLEAR NEED FOR IMPROVED METHODS OF dietary assessment.[1,2] Despite advances in computer technologies to standardize methods and streamline analysis through software, traditional methods are still prone to substantial error and bias.[3-5] A main contributor to bias is reliance on self-report without the ability to verify the dietary information, which typically leads to underreporting of energy intake (EI), especially problematic in overweight and obese populations.[4,6-13] Despite the bias, self-report obtains valuable information about the foods people consume.

Due to the limitations of self-report and the perception that images may increase objectivity (a picture is worth a thousand words), various methods of image-assisted dietary assessment have been developed, pilot tested, or validated.[14-19] Image-assisted dietary assessment refers to any method that uses images/video of eating episodes to enhance self-report of traditional methods, or uses images/video as the primary record of dietary intake. The images of foods can be captured using any device, but two distinct approaches for capturing the image have been explored: active and passive.

Active methods typically require individuals to capture images of foods with handheld devices, such as digital cameras or smartphones. Generally images are captured before and after eating episodes (to record waste) and a reference marker is placed near the foods to assist image analysis techniques (manual or automated).[20-22] Often the images of foods are supported by supplementary text or voice recordings describing the foods, or require user input to confirm details extracted from the image (within a software application), such as food type or portion size.[20,23,24] The active approach helps ensure the images obtained are relatively consistent for image analysis, but relies on users to remember to use the camera at every eating episode.

The passive approach uses wearable cameras to automatically capture point-of-view images of daily events, including eating episodes, with virtually no user input. Thus, passive image capture does not rely on users to capture images of foods; however, the images captured are not directed specifically at foods, nor do they contain a reference marker to assist analysis. A novel aspect of passive image capture, in comparison to active methods, is the ability to aid memory recall during retrospective assessment without the need for

the user to manually record dietary intake during the assessment period.[18,25]

Due to a variety of technologies suitable for use in image-assisted methods, and the differences between the active and passive approach, there is a diverse range of methods not previously examined or easily compared. Stumbo and colleagues[26] detailed the methods employed in selected image-assisted methods in development (yet to be validated), and Illner and colleagues[27] examined the strength and weaknesses of several innovative technologies in dietary assessment. However, to date no review has examined the current evidence regarding the use of image-assisted dietary assessment methods. The aim of this review was to examine all studies that have evaluated or validated an image-assisted method of dietary assessment compared with a reference method for assessing dietary EI. Due to the diversity of image-assisted methods identified, we grouped and categorized methods that employ similar methodologies for comparison.

METHODS

Eligibility Criteria

All studies that evaluated or validated an image-assisted method of dietary assessment compared to a reference method for assessing dietary EI were included. Technical reports associated with the studies and methods of image-assisted dietary assessment included were only used to support the description of the method and supporting systems used.

Exclusion Criteria

Studies that did not report EI or compare EI with a reference method were excluded. Methods of image-assisted dietary assessment under development that have not been evaluated among users described in technical reports were excluded. Studies that used precaptured images or image databanks to assist portion size estimation in traditional methods of dietary assessment were also excluded.

Information Sources and Search Strategy

Five electronic databases were searched: MEDLINE, PubMed, Web of Science, the Cumulative Index to Nursing and Allied Health Plus, and ProQuest. The searches were conducted during November 2013. A search strategy was developed using a combination of Medical Subject Headings and key words. The search string was modified where appropriate for use in the other databases. Search limiters included English language, human participants, and studies reported between 1998 and the search date to ensure all technologies evaluated in image-based methods were identified. (See Figure 1 for an example search strategy for MEDLINE database.) A manual search of included articles reference sections, and associated websites, supplemented the search of electronic databases. Corresponding authors of identified image-assisted methods in development (not evaluated or validated among users) were contacted to identify any additional studies. The search results from all databases and the manual search were imported into a reference software package EndNote (version 16, 2012, Thomson Reuters). After the removal of duplicates, the title and abstracts were screened by one reviewer (L. G.). The full-text studies that appeared relevant were then obtained and screened. Manuscripts potentially eligible for inclusion were discussed and their inclusion or exclusion were agreed upon by two authors (L. G. and C. N.).

Example Search Strategy
Source: MEDLINE[a]

1. exp[b] Technology/[c]
2. exp Cellular Phone/
3. smartphone$[d].mp.[e]
4. mobile phone$.mp.
5. mobile telephone$.mp.
6. personal digital assistant.mp.
7. PDA.mp.
8. exp Computers, Handheld/
9. tablet computer.mp.
10. device.mp.
11. life-logging.mp.
12. exp Video Recording/
13. video.mp.
14. image$.mp.
15. digital camera.mp.
16. wearable camera.mp.
17. sensecam.mp.
18. wearable sensor.mp.
19. camera.mp.
20. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19
21. exp Nutrition Assessment/
22. exp Dietetics/mt [Methods]
23. dietary assessment.mp.
24. exp Diet/is, mt [Instrumentation, Methods]
25. exp Diet Surveys/
26. exp Nutrition Surveys/
27. 21 or 22 or 23 or 24 or 25 or 26
28. 20 and 27
29. limit 28 to (english language and humans and yr="1998 -Current")

[a]Appropriate search terms utilized for other databases.
[b]exp=exploded
[c]Medline Subject Heading for MEDLINE
[d]$=any character
[e]multi-purpose search [mp.] = Title, Original Title, Abstract, Subject Heading, Name of Substance, and Registry Word fields.

Figure 1. MEDLINE search strategy for the systematic review examining the evidence for image-assisted methods of dietary assessment. [a]Appropriate search terms used for other databases. [b]exp=exploded. [c]Medline Subject Heading for MEDLINE. [d]$=any character. [e]multipurpose search [mp.]=Title, Original Title, Abstract, Subject Heading, Name of Substance, and Registry Word fields.

Data Extraction

Data extraction was conducted by one reviewer (L. G.) using a custom data extraction form to extract general study details as follows: participant characteristics sex, age, and body mass index; inclusion/exclusion criteria; study setting; method of