

Using a Wearable Camera to Increase the Accuracy of Dietary Analysis

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Background: Food diaries are commonly used to assess individual dietary intake in both the general and sporting populations. Despite the widespread use of such diaries, evidence suggests that individuals' self-reported energy intake frequently and substantially underestimate true energy intake.

Purpose: To examine the use of the Microsoft SenseCam wearable camera to help more accurately report dietary intake within various sporting populations.

Methods: In 2011, a total of 47 participants were recruited to take part in this study (17 trainee jockeys, 15 elite Gaelic footballers, and 15 healthy physically active university students). Participants wore a SenseCam for 1 day (from morning until night) while simultaneously keeping a 1-day food diary. Comparisons were made between the energy intake reported in the food diary alone and the food diary in conjunction with information gathered from the SenseCam. Data analysis was conducted in 2012.

Results: Mean total calorie intake using diary alone and diary and SenseCam were 2349 ± 827.9 kcal vs 2631 ± 893.4 kcal for the trainee jockeys; 2600 ± 521.9 kcal vs 3191 ± 770.2 kcal for the Gaelic footballers, and 2237 ± 318.5 kcal vs 2487 ± 404.6 kcal for the university students. This represented a difference of 10.7% ($p \leq 0.001$); 17.7% ($p \leq 0.001$); and 10.1% ($p \leq 0.01$) among measurement methods for trainee jockeys, Gaelic footballers, and university students, respectively.

Conclusions: Results from this first-generation study suggest that a more accurate estimate of total energy intake is provided when combining the use of a conventional food diary and a SenseCam. Additional information on portion size, forgotten foods, leftovers, and brand names can be obtained by using this novel sensing technology in conjunction with the diary, with improved dietary assessment a potential outcome.

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Background

Providing accurate dietary advice is vital when working with athletes whose performance depends on achieving an optimal body mass while remaining in peak physical condition. Food intake has long been highlighted as a strong indicator of performance¹ and is associated with disease outcome and prevention.² The importance of being able to accurately and reliably evaluate dietary intake is of value across a range of

populations for the purpose of regulating calorie intake to maintain an optimal body mass for health as well as athletic performance.

Food diaries are the traditional method of assessing energy intake and have been commonly used for dietary analysis because of their non-invasive nature and ease of administration.^{3–5} Despite the widespread use of food diaries across a range of populations, their accuracy is dependent on meticulous logging by the individual, and a tendency appears for calorie intake to be substantially underestimated. Self-reported energy intake is shown to frequently and substantially underestimate true energy intake by approximately 20%–47%.^{6–10} Under-reporting appears to be most prevalent among individuals who are overweight¹¹ or trying to control their weight, but has also been shown to occur in participants of normal weight.¹² Also, subjects may report what they perceive to be a “more healthy” food intake than that actually

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consumed, in an attempt to impress others or avoid criticism.¹¹

In recent years, technologic advances have resulted in the introduction of small, lightweight electronic recording devices, providing an opportunity to bring greater precision and accuracy to dietary assessment. Such photographic food recording methods involve participants manually taking photographs of their meals before and after they finish to analyze the number of calories consumed. This method, however, requires individuals to always carry a camera and to remember to take a picture of the food consumed. No advantage in accuracy over food diaries has been reported.^{13,14} Further, some groups of individuals appear to prefer the use of food diaries over photographic techniques, in the belief that taking photographs is less convenient than using food diaries.¹⁵ Because of the inherent measurement error typically associated with conventional food diaries,^{16,17} there appears to be a need for a more precise non-invasive method of dietary assessment that would facilitate increased accuracy of dietary assessment while minimizing respondent burden.

The Microsoft SenseCam,¹⁸ a small lightweight camera worn around the neck, may help the assessment of dietary intake, as it automatically takes pictures without any input required from the subject, decreasing the likelihood of misreporting. The SenseCam was initially used in a clinical setting as a tool for understanding the mechanisms of memory and cognitive functioning. The efficacy of using such a novel technology to increase the accuracy of dietary assessment remains to be determined but has the potential to provide a viable alternative to either replace or augment traditional methods. The purpose of this exploratory study was to examine the use of the SenseCam wearable camera to help more accurately report dietary intake in three different populations.

Methods

Participant Selection

In 2011, a total of 47 subjects volunteered to participate in the study. Subjects consisted of 17 trainee jockeys (male $n=13$, female $n=4$, age 18 ± 2 years); 15 elite collegiate Gaelic footballers (male $n=15$, age 22 ± 1 years); and 15 physically active university students (male $n=10$, female $n=5$, age 23 ± 1 years).

The trainee jockeys were recruited from Ireland's Racing Academy and Centre of Education (RACE) and consequently resided at the training academy from Monday to Friday. All of their meals were provided by the in-house canteen. The Gaelic footballers were members of the Dublin City University (DCU) Sports Academy and trained at least four times per week, with a competition (game or event) at least once a week.^{19,20} The university students were recruited from the wider DCU population and were physically active, undertaking physical activity a minimum of twice a week. The Gaelic football and university student groups were free to eat in

any environment. Ethical approval for the study was granted by the DCU ethics committee. Consent was sought from each subject, and parental consent for those aged <18 years was also obtained.

Food Diary and SenseCam Measurement Techniques

Participants wore the SenseCam for 1 day, on awakening and retiring for the night, while simultaneously keeping a detailed food diary. A 1-day food diary was adapted from a 7-day food diary reported in a previously published study of jockeys' dietary intake.²¹ Participants were required to document the time at which food was consumed in addition to the food, brand name, and quantity (e.g., Yoplait full-fat strawberry yoghurt). Food types and portion sizes were recorded using household measures. Helpful hints were given in the diary along with examples for ready prepared meals and take-out meals. For example, if cheese was consumed, participants were prompted to include type of cheese, whether it was soft or hard, and regular versus low-fat. If chicken was consumed, participants were asked to specify if it was a leg, wing, and/or breast or white meat only, and whether the skin was eaten or not.

For SenseCam, subjects were asked to wear the camera around their neck and secured to their chest with a velcro strap, from day's start until day's end (excluding bathing). The SenseCam images were viewed using Vicon Revue software. Hodges¹⁸ and Guerrin²² detail the SenseCam further.

Before implementation of the study, each participant met with a qualified sports dietitian and received both verbal and written instructions on the operation of the SenseCam and on completing the diary as accurately as possible. A follow-up meeting occurred with each participant the day after testing and the data collected were reviewed. The food diaries were scrutinized in the presence of each individual so that any ambiguities regarding the quantity, incomplete entries, or vague descriptions could be resolved at that time. Details from the food diary were cross-referenced with a food reference manual.²³

The footage from the SenseCam was then reviewed in the presence of each individual participant and any extra foods consumed or differences in portion size were documented. At this point, it was possible to note specific food brands consumed and also if there were any leftovers after the meal had been eaten (Figure 1). The two sets of recorded information, the diary alone and the diary plus SenseCam information, were entered into a dietary analysis package (Windiets) that allowed determination of total calorie intake.

Data Analysis

Data were prepared in 2012, using SPSS, version 16.0. A paired t test ($p\leq 0.05$) was used to explore whether there was a difference between the mean calorie intake from the diary alone versus from the diary plus SenseCam combination.

Results

Six (35%) of the trainee jockey group; 5 (33%) of the Gaelic footballers group; and 2 (13%) of the university student group were removed from the final data analysis because of incomplete data being recorded caused by a combination of camera or user error, leaving 11, 10, and 13 participants to be analyzed, respectively. Only one participant from all groups (female jockey) had a food



Figure 1. Images from the Microsoft SenseCam showing food consumed by the subject
 Note: (a) an individual's dinner, allowing the extra condiment about to be put on the plate to be remembered; (b) a breakfast image allowing questions regarding portion size

diary that matched the information obtained from the SenseCam.

Mean total calorie intake amounts using diary alone when compared with the combination of the diary plus SenseCam were as follows: 2349 ± 827.9 kcal vs 2631 ± 893.4 kcal for the trainee jockeys; 2600 ± 521.9 kcal vs 3190 ± 770.2 kcal for the Gaelic footballers; and 2237 ± 318.5 kcal vs 2487 ± 404.6 kcal for the university students (Figure 2). Differences among measurement methods of 10.7% ($p \leq 0.001$); 17.7% ($p \leq 0.001$); and 10.1% ($p \leq 0.01$) were reported for the trainee jockeys, Gaelic footballers, and university students, respectively (Table 1).

Discussion

The results of this initial study suggest that the SenseCam may provide useful benefits in terms of augmenting established techniques for recording energy intake. The images obtained from the SenseCam provide additional information regarding dietary intake patterns and highlighted a significant under-reporting of calorie intake, ranging from

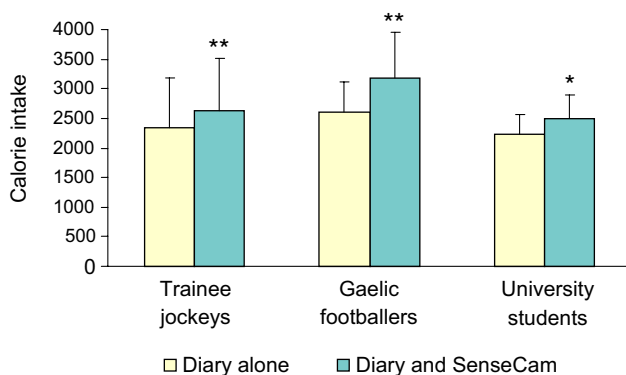


Figure 2. Comparison of energy intake using two assessment methods: diary alone, and diary with Microsoft SenseCam

* $p \leq 0.01$, ** $p \leq 0.001$

10% to 18% in the populations studied. To the authors' knowledge, no previous research has been published examining the potential use of the SenseCam for dietary assessment. The current study thus stands as a proof of concept, indicating the potential value of the SenseCam in dietary analysis.

The automatic nature of the SenseCam offers many advantages over studies using

a user-activated camera to log foods. Requesting that individuals manually photograph before–after images of meals is dependent on subject compliance, is potentially intrusive, and requires the individual to remember not only the camera but also to take photographs at appropriate times. Previous studies^{13–15,24} have reported no general advantage in terms of accuracy in using a conventional camera to capture dietary intake over food diaries because of participant burden and incomplete photographic food records.

The process of recording food consumption has been shown previously to influence habitual dietary practices to the extent that alternate choices may be made, as participants are aware that their diary will be analyzed.²⁵ During the current study, each subject wore the SenseCam and simultaneously completed a food diary for a 1-day period. When conducting dietary analysis over more extended periods, the SenseCam may become more valuable because of decreased enthusiasm for diary logging by participants over time. Previous studies published by the current authors' research group have used a 7-day food diary to gain insight into the dietary practices of jockeys. However, as with all dietary assessment methods, under-reporting was evident.²¹ Use of the SenseCam provides a mechanism to check the accuracy of the diary and, because it works automatically, is not subject to reporting biases.

The SenseCam provides a “fly on the wall” view of critical events during the subject's day. Many factors may

Table 1. Mean difference in energy intake between two dietary assessment methods, M ± SD

	Mean difference (kcal)	Mean difference (%)
Trainee jockeys	282 ± 164	10.7**
Gaelic footballers	591 ± 304	17.7**
University students	250 ± 216	10.1*

* $p \leq 0.01$, ** $p \leq 0.001$

explain the differences in calorie intake measured by the diary versus the SenseCam in the current study. The automated nature of images captured on the SenseCam (up to 3000 photos per day) forms a comprehensive visual record of eating habits. This facilitates an image-by-image discussion with a dietitian, prompting questioning around what occurred during the day along with places visited (e.g., stopping at a garage where snacks were bought). Such questioning helps to jog an individual's memory and report more accurately what has been consumed.

The dietitian can observe leftover foods, which are commonly undocumented in food diaries. Different food brand types can be identified, allowing a more precise assessment of energy intake in addition to a more accurate idea of portion size. Despite precise written and verbal instruction on how to accurately complete a food diary, there was, as found with other populations, a clear lack of ability to determine portion size in the current study sample. Of relevance to this observation, previous research has found that young adults experience portion distortion with some foods.²⁶ The current study results highlight the continued need for more education around portion size. Small discrepancies in isolation may appear unimportant, but when accumulated over the course of a day may account for the noticeable under-reporting that occurs in a large proportion of diaries.

Limitations

Despite the potential benefits of the SenseCam, there were limitations associated with its use because of both user and camera error. Data captured with SenseCam were incomplete for a number of participants. As a consequence, the results from 13 subjects (28%) were removed before the final data analysis. Despite the provision of simple instructions on how to operate and wear the camera, subjects repeatedly made errors, such as not wearing the camera properly and pressing the wrong buttons to switch it on and off. There were also some initial software problems that needed to be overcome.

Some photos were of low quality in poorly lit or dark conditions as no flash or infrared photo capture capabilities exist for the SenseCam. Because it was a proof-of-concept study, only a 1-day period was investigated. Ideally, 3–7 days should be monitored in order to accurately assess nutritional intake.^{25,27} The SenseCam does not enable the automated estimation of the volume of the foods captured in the images.¹⁴ Further, it does not provide information on the calories consumed.

Future Research

Further research is required to investigate the efficacy of using the SenseCam for the purpose of dietary analysis in other population groups. The SenseCam may have many

possible applications where therapeutic diets are used, enabling the dietitian to more accurately assess what an individual is consuming. Additionally, it can be used as an educational tool for the discussions of portion control and other relevant topics between the dietitian and the individual.

Research is currently underway to develop an application that could be used on smartphones, which are becoming increasingly accessible to a wide range of populations.²² A recent study also describes an exciting new technology—a portable wearable device, which can passively capture images of foods consumed and which incorporates a unique method of portion size quantification.²⁸ The information being captured can subsequently be automatically fed back to the dietitian's computer.

A system whereby energy expenditure was simultaneously recorded would further assist in the delivery of precise individualized dietary recommendations. To gain a more accurate view of an individual's habitual intake, it is generally recommended that a minimum of 3–7 days of dietary intake be recorded.^{25,27} It is also important to note that the SenseCam works best currently as an adjunct to an existing dietary assessment method such as a food diary, as opposed to as a stand-alone method. The diary provides the template to work from, and the camera helps fill in the gaps on elements such as portion size, any missed condiments, leftovers, drinks, snacks, and brands of foods consumed.

Conclusion

A difference was reported in the mean total calorie intake of the diary alone compared to the SenseCam and the diary. Results from this study suggest that a more accurate estimate of total energy intake is provided using the diary in conjunction with the SenseCam. Additional information on portion size, forgotten foods, leftovers, and brand names could be obtained by using wearable cameras in conjunction with the diary, with the potential to improve dietary assessment in a number of different populations. Although this study focused primarily on healthy, athletic populations, the potential benefits of the SenseCam in dietary analysis indicate that dietitians and other health providers can more accurately assess and assist those in need of dietary management to meet their nutritional as well as broader health requirements. Overall, the results of the current study indicate that the SenseCam may provide a valuable tool in the assessment of food intake through verifying and expanding on the data captured using a conventional diary, thereby augmenting the accuracy of the dietary information provided.

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