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EDITORIAL

Can we measure food intake in humans?

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Human food intake behavior results from extremely complex interactions of both internal homeostatic, hedonic and cognitive signals with external environmental cues [1], coordinated through various neuronal pathways [2]. The impressive research advances to understand the regulation of food intake have unfortunately not limited the progression of obesity which remains a growing worldwide problem.

Yet, accurately quantifying food intake is essential in epidemiology studies, to understand the effect of diet on health and diseases and in clinical trials, to evaluate the efficacy of lifestyle interventions. Because energy intake is linked to meal size [3, 4], granular studies of food intake at a single meal are also particularly needed to understand the determinants of excess food intake.

While the method chosen to quantify food intake depends on the research question and the time-period of assessment (one meal vs. 1 week for example), the method selected needs to show reliability, i.e., consistency during test-re-test and in different experimental situations and validated against the gold standard method. This is unfortunately not always the case.

Energy balance studies and weight loss interventions require accurate measurement of calorie intake [5]. To date, food records, food frequency questionnaire and/or 24-h diet recalls are still the most common methods to assess energy and dietary intake, in spite of their notorious inaccuracy when compared to doubly labeled water (DLW), the gold standard [6].

DLW coupled with the measure of body energy stores accurately calculates ambulatory energy expenditure and energy intake over a defined period of time [5]. DLW is the gold standard to measure energy intake in ambulatory setting, over a 2-week period, and is very helpful for energy balance studies.

While an expensive research tool requiring expertise that few researchers have access to, it should be used more to validate all sorts of instruments, sensors and digital platforms being developed to measure ambulatory ingestive behavior. Cheaper alternatives have been proposed to estimate energy intake from total energy expenditure [7].

The number of commercial smartphone applications to assess food intake has exploded. Most of these commercial applications do not provide data usable for research. The use of smartphone technology and digital photography in research setting allows remote granular assessment of meal timing and estimates of energy intake, in real-time, with limited user burden and at low cost [8]. While this technology eases self-reporting and likely increases its accuracy, it still has many limitations inherent to self-report, to the inaccuracies in the assessment of portion size and or meal composition from images, and to the high burden related to data analysis [9]. Future advance technology and artificial intelligence should allow faster analysis of larger datasets, and include methods for meaningful feedback to users, in real-time [9].

However, like diet recalls by questionnaires, smartphone technology still has limitation inherent to self-reporting, which, by itself, can modify the behavior being monitored. Methods for passive data capture combining camera and chewing detector, to estimate spontaneous ad libitum meals in free-living individuals, will become important research tools [10], when becoming less intrusive and when cross-validated in laboratory setting with the universal eating monitor (UEM), and, in ambulatory setting, with DLW. As of today, neither camera images nor chewing can yet accurately quantify the amount of ingested food.

Studies on metabolic and/or health consequences of food intake require data acquisition on diet quality, nutrients composition, whether the food is plant versus animal based, unprocessed, minimally processed or ultra-processed [11], on the cooking method used, and on meal pattern [12]. This detailed diet information can be coupled with metabolic studies. The precise quantitative measure of an infinite number of urine and blood biomarkers offers the opportunity to track diet composition, including macronutrients [13] and its metabolic consequences [14]. While the potential of nutri-metabolomics to assess dietary exposure is enormous, the complexity of sample analysis, the lack of standardization of platforms across laboratories, the need for comprehensive libraries and sophisticated statistical methods of data analysis, together with the high cost, hampers, at least for now, its immediate translational applicability [14].

The understanding of the mechanisms of the various components of meal structure requires well-controlled laboratory studies [15, 16]. The initiation and termination of a single meal are tightly regulated with distinct physiological characteristics that has been shown to be perturbated in various disease phenotypes.

The Edogram, developed in 1969, allowed a better understanding of the role of food texture, palatability, deprivation and calorie density on chewing, swallowing, eating rate, and satiety [17]. Later, the UEM, developed to measure cumulative intake curves for either solids or liquids, allowed a quantitative measure of ingested food, in laboratory setting [16]. The rate of eating, a key determinant of food intake, is under physiological control and can be used as an indicator of health or disease. Indeed, faster eating rate facilitates overeating and is associated with obesity. Eating rate measure needs to be combined with energy density to capture energy intake [18–20] UEM studies can be used for cross validation with wearable such as bite counter, or in pharmacological studies of drug targeting obesity [15]. While the measure of food intake during one meal is valuable, it does not translate in assessment of energy balance [21]. However, more prolonged inpatient studies can monitor ad libitum food intake, coupled with other metabolic outcome, over 24 h or days.

Can we accurately measure food intake? I am very grateful for the authors who contributed to this Special issue on Validated Measures of Food Intake in Humans, reviewed old and new methods, discussed remaining challenges and futuristic views to improve accuracy under free-living conditions and in laboratory setting.

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DLW for field studies [5] and cumulative intake curves in laboratory setting [16] are the only methods that provide accurate quantitative measure of energy and/or food intake. However, the complex elements of food intake behavior and its metabolic consequences could be assessed by combining various methods, self-report with smartphone and passive capture of behavior, DLW and nutria-metabolomics for ambulatory setting. The future of digital platforms, wearables, machine learning with automated feedback will allow to simultaneously assess behavior, deliver intervention, monitor adherence, and identify barriers to lifestyle optimization. These tools, when fully validated, will transform lifestyle interventions into precise and personalized interventions.

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REFERENCES

1. Cruwys T, Bevelander KE, Hermans RC. Social modeling of eating: a review of when and why social influence affects food intake and choice. Appetite. 2015;86:3–18.
2. Watts AG, Kanoski SE, Sanchez-Watts G, Langhans W. The physiological control of eating: signals, neurons, and networks. Physiol Rev. 2022;102:689–813.
3. Rolls BJ, Roe LS, Meengs JS. Larger portion sizes lead to a sustained increase in energy intake over 2 days. J Am Diet Assoc. 2006;106:543–9.
4. Jeffery RW, Rydell S, Dunn CL, Harnack LJ, Levine AS, Pentel PR, et al. Effects of portion size on chronic energy intake. Int J Behav Nutr Phys Act. 2007;4:27.
5. Ravelli MN, Schoeller DA. An objective measure of energy intake using the principle of energy balance. Int J Obes. 2021;45:725–32.
6. Schoeller DA, Thomas D, Archer E, Heymsfield SB, Blair SN, Goran MI, et al. Self-report-based estimates of energy intake offer an inadequate basis for scientific conclusions. Am J Clin Nutr. 2013;97:1413–5.
7. Drummen M, Adam TC, Macdonald IA, Jalo E, Larssen TM, Martinez JA, et al. Associations of changes in reported and estimated protein and energy intake with changes in insulin resistance, glycated hemoglobin, and BMI during the PREVIEW lifestyle intervention study. Am J Clin Nutr. 2021;114:1847–58.
8. Manoogian ENC, Wei-Shatzel J, Panda S. Assessing temporal eating pattern in free living humans through the myCircadianClock app. Int J Obes. 2022;46:696–706.
9. Höchsmann C, Martin CK. Review of the validity and feasibility of image-assisted methods for dietary assessment. Int J Obes. 2020;44:2358–71.
10. Doulah A, Ghosh T, Hossain D, Marden T, Parton JM, Higgins JA, et al. Energy intake estimation using a novel wearable sensor and food images in a laboratory (pseudo-free-living) meal setting: quantification and contribution of sources of error. Int J Obes. 2022;46:2050–7.
11. Hall KD, Ayuketah A, Brychta R, Cai H, Cassimatis T, Chen KY, et al. Ultra-Processed Diets Cause Excess Calorie Intake and Weight Gain: An Inpatient Randomized Controlled Trial of Ad Libitum Food Intake. Cell Metab. 2020;32:690.
12. Mattson MP, Allison DB, Fontana L, Harvie M, Longo VD, Malaisse WJ, et al. Meal frequency and timing in health and disease. Proc Natl Acad Sci USA 2014;111:16647–53.
13. Prentice RL, Pettinger M, Neuhouser ML, Raftery D, Zheng C, Gowda GAN, et al. Four-Day Food Record Macronutrient Intake, With and Without Biomarker Calibration, and Chronic Disease Risk in Postmenopausal Women. Am J Epidemiol. 2022;191:1061–70.
14. Gonzalez-Dominguez R, Jauregui O, Mena P, Hanhineva K, Tinahones FJ, Angelino D, et al. Quantifying the human diet in the crosstalk between nutrition and health by multi-targeted metabolomics of food and microbiota-derived metabolites. Int J Obes. 2020;44:2372–81.
15. Kissileff HR. The Universal Eating Monitor (UEM): objective assessment of food intake behavior in the laboratory setting. Int J Obes. 2022;46:1114–21.
16. Westerterp-Plantenga MS. Eating behavior in humans, characterized by cumulative food intake curves–a review. Neurosci Biobehav Rev. 2000;24:239–48.
17. Bellisle F. Edograms: recording the microstructure of meal intake in humans-a window on appetite mechanisms. Int J Obes. 2020;44:2347–57.
18. Forde CG, Mars M, de Graaf K. Ultra-Processing or Oral Processing? A Role for Energy Density and Eating Rate in Moderating Energy Intake from Processed Foods. Curr Dev Nutr. 2020;4:nzaa019.
19. Robinson E, Almiron-Roig E, Rutters F, de Graaf C, Forde CG, Tudur Smith C, et al. A systematic review and meta-analysis examining the effect of eating rate on energy intake and hunger. Am J Clin Nutr. 2014;100:123–51.
20. Westerterp-Plantenga MS, Westerterp KR, Nicolson NA, Mordant A, Schoffelen PF, ten Hoor F. The shape of the cumulative food intake curve in humans, during basic and manipulated meals. Physiol Behav. 1990;47:569–76.
21. Edholm OG, Fletcher JG, Widdowson EM, McCance RA. The energy expenditure and food intake of individual men. Br J Nutr. 1955;9:286–300.

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COMPETING INTERESTS

The author declares no competing interests.

ADDITIONAL INFORMATION

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