Perspective: Novel Approaches to Evaluate Dietary Quality: Combining Methods to Enhance Measurement for Dietary Surveillance and Interventions

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ABSTRACT

Refining existing dietary assessment methods to reduce measurement error and facilitate the routine evaluation of dietary quality is essential to inform health policy. Notable advancements in technology in the past decade have enhanced the precision and transformation of dietary assessment methods with applications toward both population health and precision nutrition. Within population health, innovative applications of big data including use of automatically collected food purchasing data, quantitative measurement of food environments, and novel, yet simplified dietary quality metrics provide important complementary data to traditional self-report methods. Precision nutrition is similarly advancing with greater use of validated biomarkers for assessing dietary patterns and understanding individual variability in metabolism. Concurrently enhancing our understanding of diet–disease relations at the population health and precision nutrition levels provides tremendous potential to generate evidence needed to advance public health nutrition policy. This commentary highlights the importance of these advances toward progressing the field of dietary assessment and discusses the application of food purchasing data, data analytics, alternative dietary quality metrics, and -omics technology in population and clinical medicine. *Adv Nutr* 2022;13:1009–1015.

Statement of Significance: The present work synthesizes the application of emerging technologies in dietary assessment toward population health and clinical practice. Notably, it highlights how concomitant use of novel technologies enhances traditional methods and helps address their limitations to robustly characterize dietary quality and diet–disease relations.

Keywords: technological advancement in dietary assessment, personalized dietary guidance, multidimensional diet assessment, population health, NOVA classification, biomarkers, nutrigenomics, precision nutrition

Introduction

Developing strategies to enhance the validity, reliability, and ease of evaluating dietary quality is at the crux of advancing our ability to address the multi-level determinants of diet-related chronic disease (1). Although traditional self-reported dietary assessment methods like dietary recalls and FFQs will likely remain an integral component of evaluating dietary quality, measurement error, systematic bias, and limitations in the scope and routine implementation of these tools necessitate innovation in the strategies we use to assess diet (2). Notably, in the past decade, technological advances in data analytics and "*-omics*" have addressed some of these limitations and enabled more widespread application of methods previously used in isolation or with considerable researcher and/or participant cost. These advancements have shaped precision nutrition on one end of the spectrum that enhances clinical practice and public health nutrition on the other that is necessary for population health. A goal of this

 Adv Nutr 2022;13:1009–1015; doi: https://doi.org/10.1093/advances/nmac007.

commentary is to underscore the practicality of routinely evaluating dietary quality and consider how greater use of food purchasing data and/or the NOVA framework could facilitate making evaluation of dietary quality as ubiquitous as blood pressure screening in pharmacy settings.

Technological advancements in dietary assessment methods undoubtedly improve the scope, objectivity, and frequency of dietary assessment at the population level while also enhancing the validity, precision, and reliability of dietary measures at the individual level. Routinely collected technology-enabled data on food purchasing and greater utilization of nutrition environment measurement tools allow for dynamic evaluation of drivers of dietary quality in the broader food system that contribute to health disparities, including food production, distribution, and marketing practices. Simultaneously, breakthroughs in *-omics* technology applied to precision nutrition enhance the mechanistic understanding of diet–disease pathways by relying on objective dietary biomarkers (3) that could serve as indicators of dietary quality. Gleaning insight about diet–disease relations at both the clinical and population-health ends of the spectrum creates tremendous potential for developing more effective nutrition policies (**Figure 1**).

Dietary patterns are dynamic and shaped by numerous interwoven personal and environmental factors. The NIH increasingly recognizes that precision nutrition must encompass factors that extend beyond what people eat, but also how variability in dietary behaviors, genetics, the microbiome, and socioeconomic and physical environments modify disease risk (4, 5). Comprehensive dietary assessment methods that capture the multidimensionality of diet and incorporate measures of our food environment will enhance accuracy by measuring the within- and between-person heterogeneity necessary to holistically characterize individual and population-level dietary quality. Technological advancements in dietary assessment remain promising adjuvants to self-report methods to enhance capture of dietary patterns and expand upon the one-size-fits-all approaches to dietary interventions.

Combining assessment methods across varying levels of the food system [e.g., dietary quality of household grocery purchases or Nutrition Environment Measures (NEMS)] (6) with existing individual-level methods (e.g., 24-h recalls) and dietary biomarkers is compelling. By using multiple methods to enhance accuracy in dietary assessment, it is feasible to capture smaller levels of responsiveness among individuals in relation to dietary interventions, better understand environmental and intraindividual mechanisms that influence diet–disease associations, reduce self-report error, and more routinely and inexpensively monitor diet as a vital sign and noncommunicable disease risk factor.

This commentary will highlight recent innovations in the application of dietary assessment methods that reflect the food system and the food environment and demonstrate how concurrent evaluation of dietary quality at the environmental and individual level can enhance the sensitivity of dietary assessment to detect small changes in dietary quality. Specifically, we will discuss: *1*) the promise of leveraging technology to automatically analyze grocery purchase data to evaluate dietary quality, *2*) applications of adjuvant dietary quality indices (i.e., NOVA) that consider the processing level of foods as a distinct element of dietary quality, and *3*) the value of combining traditional diet assessment methods with individual-level biomarkers to inform understanding of the smallest detectable differences that can be achieved through dietary interventions.

The underutilized role of food purchasing data in dietary assessment

Food environments exert a powerful influence on individual food choice and subsequent dietary quality (7). Neighborhoods vary considerably with respect to availability, appeal, price, and marketing of healthy and unhealthy foods, and those factors along with upstream policies that shape food environments influence what foods are available in the home and are subsequently consumed. The widely used Healthy Eating Index (HEI) has been used to assess both individual-level dietary quality and the dietary quality of food purchases. However, calculating the HEI requires access to a detailed nutrient database, limiting its utility — particularly in just-in-time-adaptive dietary interventions that require recurrent, unobtrusive, evaluation of dietary quality. As interest grows in modifying food environments to promote better dietary quality and subsequently, health outcomes, numerous efforts have been made to evaluate food purchase quality more seamlessly. Brewster et al. developed and validated the Grocery Purchase Quality Index (GPQI), making the calculation of grocery purchase quality simpler by eliminating the need for a nutrient database (8). The recently completed Smart Cart Study piloted a novel application of food purchasing data by iteratively coding daily individual-level receipt data to measure grocery purchase quality and identify areas for dietary quality improvement using the GPQI (9). Moreover, research supports the use of food purchasing data, even only partial data, as a valid measure of dietary quality (10, 11). Additional research examining the sensitivity of grocery purchase quality to dietary intervention, its utility as a complementary dietary assessment method, and the feasibility of continuously monitoring the quality of grocery purchases at the population level is warranted.

This work was supported by a New Innovator in Food and Agricultural Research Award from the Foundation for Food and Agricultural Research (grant 534298). The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.
Author disclosures: The authors report no conflicts of interest.
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Abbreviations used: DASH, Dietary Approaches to Stop Hypertension; GPQI, Grocery Purchase Quality Index; HEI, Healthy Eating Index; MedDiet, Mediterranean diet; UPC, Universal Purchase Code.

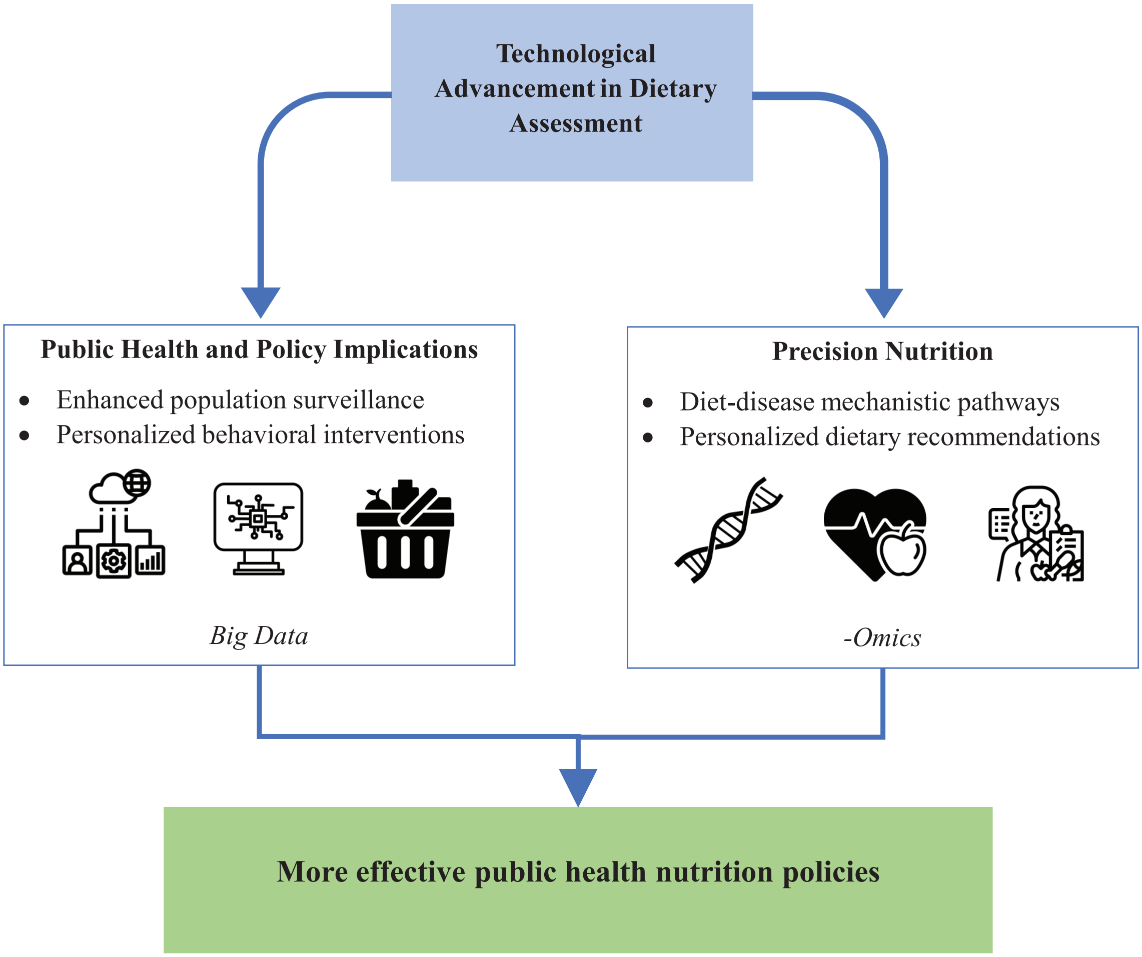

FIGURE 1 Pathways through which technological advancements in dietary assessment advance population health, precision nutrition, and public health nutrition policy. Images were used with permission from the Noun Project including, Big data by Nithinan Tatah; Big data by Valeriy; shopping basket by ProSymbols; DNA by varvarvarvarra; nutrition consultant by Wichai Wi; healthy by WEBTECHOPS LLP.

Despite the promise of using food purchasing data for seamlessly and continuously evaluating dietary quality, challenges remain with respect to the degree of human labor necessary to classify grocery purchases into food groups used to calculate the GPQI score. The process of categorizing Universal Purchase Codes (UPCs) and brief text descriptions from customer receipts into 11 GPQI categories and nonfood items is complex because UPC codes vary across retailers and stores regularly add new foods or items. Such classification problems, however, may be ameliorated with applications of machine learning — particularly natural language processing. Recently, the Smart Cart Study team partnered with computer scientists to develop a supervised classification algorithm to automatically classify purchasing data from the Smart Cart Study and open-source data from the Open Grocery database hosted using Amazon Web Services (AWS). The algorithm identified key terms from the product's text description on the receipt to classify it into a food group using a logistic regression package in Python, with 75% of data used for training and 25% for testing. Accuracy ranged from 76 to 97% (mean 84%) depending on the food group for the 29,000 UPCs coded to date. With ongoing development of this algorithm to improve accuracy, it will become more feasible to use food purchasing data to monitor the effectiveness of dietary interventions or estimate the dietary quality of different populations using automatically collected data from grocery stores. Beyond the benefits of less expensive, semi-automated dietary quality monitoring as a tool to use in dietary interventions and for population surveillance, food purchasing data represents a form of objective nonself-reported dietary data potentially useful for reducing measurement error in self-reported dietary assessment methods. Because the measurement error structure differs between self-reported dietary assessment and dietary quality estimated from objective purchasing data, combining these metrics has the potential to improve precision of dietary estimates and overall, reduce bias associated with diet and health research.

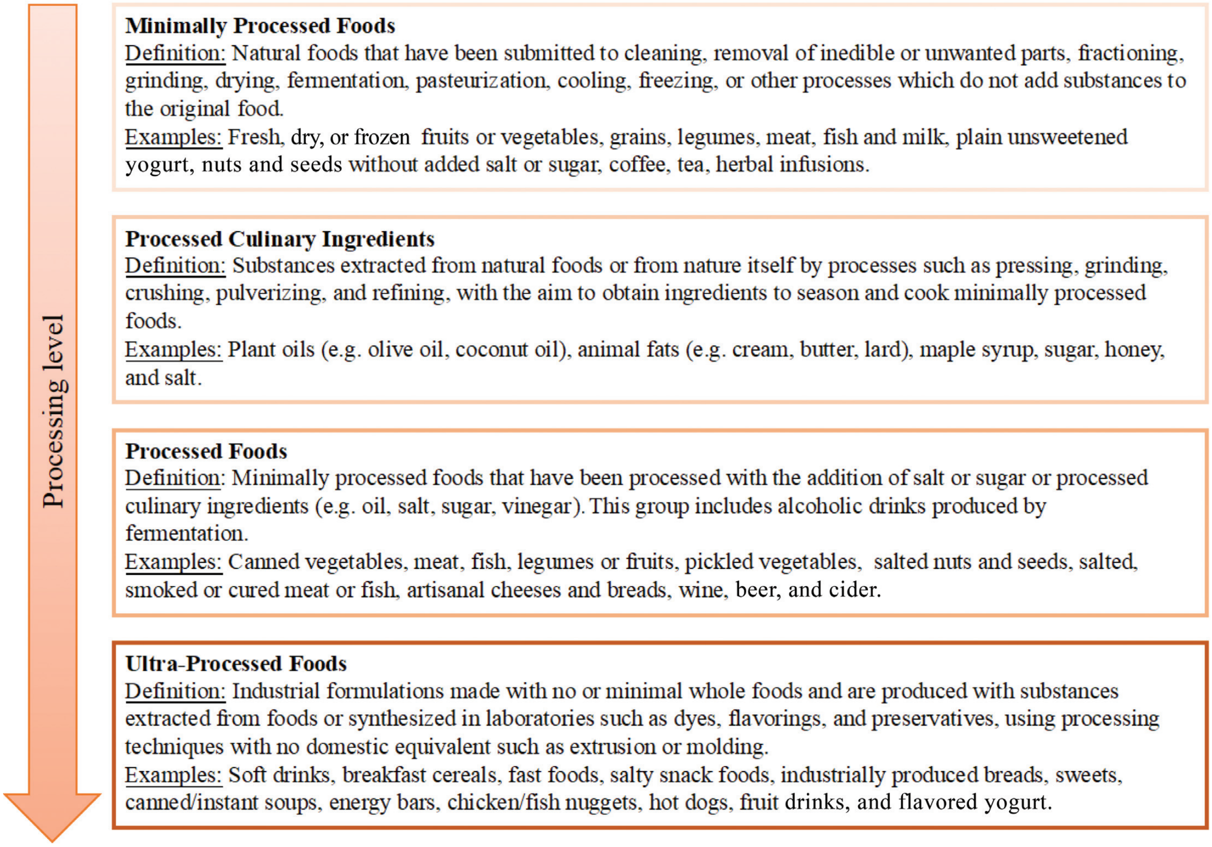

FIGURE 2 The NOVA framework categorizes foods into 4 mutually exclusive categories based on the extent and purpose of industrial processing (12).

Food processing level as a complementary metric to assess dietary quality

Monitoring food purchasing data also provides an opportunity to assess an emerging cardiovascular risk factor, the proportion of ultra-processed foods. Diets and food supplies worldwide are increasingly based on ultra-processed foods, which are industrially manufactured, ready-to-eat/heat formulations containing little or no whole foods (12, 13). Ultra-processed foods provided 57.0% of total energy consumed by the US adult population in 2017–2018, a significant increase from 53.5% of total energy in 2001–2002, with intake even higher among adolescents (14, 15). Epidemiological studies have consistently found that diets high in ultra-processed foods are nutritionally unbalanced (16–19) and associated with a higher risk of obesity, cardiometabolic diseases, and cancer (20, 21). Hypothesized mechanisms include the poor nutritional quality, novel physical structure, and content of food additives and neo-formed contaminants of ultra-processed foods (22–24). As a result, processing level, most often evaluated using the NOVA framework (**Figure 2**), has emerged as a distinct dimension of dietary quality that may complement traditional metrics, such as the HEI. Like the GPQI, using NOVA as an adjuvant dietary quality metric may make it more feasible to compute dietary quality automatically with less reliance on human labor and nutrient databases; simultaneously, its distinction from other dietary quality indices may enhance its utility toward shaping food policy and the food environment.

NOVA is a specific, coherent, and comprehensive classification of food processing level that allows researchers to effectively differentiate between 4 relevant levels of food processing ranging from minimally processed to ultra-processed (25, 26). Without consideration of processing level, individual foods with diverse characteristics are often categorized within the same exposure group in nutritional studies. For example, brown rice, whole-grain crackers, and sweet whole-grain breakfast cereals are all considered sources of whole-grains yet have significantly divergent physiological effects. This approach likely limits the ability to differentiate foods with beneficial and hazardous health effects owing to processing and may lead to inconsistent and conflicting findings. Further categorizing foods by the level of processing emphasizes the differences in both nutritional quality and nonnutritional attributes (e.g., food structure, additives, mode of consumption) between foods within the same food group.

The Dietary Guidelines for Americans (DGA) 2020–2025 (27) are primarily food based, however, guidance concerning ultra-processed foods are not clearly articulated. The current guidelines are therefore unlikely to impact the awareness, knowledge, and behavioral skills required to purposefully lower intakes of ultra-processed foods. For example, current advice to choose nutrient-dense forms of foods, that are lower in added sugar, sodium, and saturated fat, may encourage consumption of "light" or "low in" versions of ultra-processed foods that include artificial sweeteners, emulsifiers, and/or other additives, rather than promoting intakes of minimally processed whole foods. Incorporating the principles of NOVA as an additional and complementary dimension of dietary guidelines and food policy may simplify dietary advice to the public and encourage healthier food environments. For example, incorporating food processing as a dimension of dietary quality may encourage some food manufactures to reconsider developing and promoting poor-quality ultra-processed foods with added beneficial components (e.g., fiber, vitamins) or reduced amounts of harmful nutrients (e.g., added sugar, sodium, saturated fat) (28). Future research should determine if food-based dietary guidelines and policies that distinguish ultra-processed from moderately and minimally processed foods can facilitate healthier food choices and improve dietary quality.

Advancements in dietary biomarkers and their role in improving diet assessment

Of equal importance to better characterizing diet–disease relations is the contribution of dietary biomarkers. Recently, the use of biomarkers, an objective quantifiable method, along with the rapid development of new high-throughput technologies (*-omics*) have emerged as a potential strategy to accurately measure diet exposure (29, 30) and address pitfalls in nutrition epidemiology.

Several specific food biomarkers have been described in the literature [e.g., trigonelline or Furoylglycine for coffee intake (31, 32); or S-methyl-L-cysteine sulphoxide and its derivatives for cruciferous vegetables (33)]. However, emerging evidence is focused on disentangling the fingerprints of dietary patterns, which is more important for understanding the relation between diet and health/disease and can ultimately move the field towards precision nutrition. In this regard, previous studies have characterized metabolic profiles of, for example, the Dietary Approaches to Stop Hypertension (DASH) pattern where the top 10 metabolites were identified to discriminate the DASH diet from 2 other dietary patterns in an 8-wk intervention study with 329 participants (34). Similarly, a larger study has recently identified a metabolic signature of adherence to the Mediterranean diet (MedDiet) using 1859 participants from the Spanish PREDIMED (Prevención con Dieta Mediterránea) trial, and 2 US validation cohorts ($n = 6868$). Specifically, the authors identified 67 metabolites, including 45 lipids, 19 amino acids, 2 vitamins, and 1 xenobiotic, which also predicted cardiovascular disease risk (35). Biomarkers and metabolomics have also been used in combination with self-reported methods to assess intervention compliance. Results from the nested biomarkers pilot study in Feeding America´s Bravest, a MedDiet cluster-randomized controlled trial (36), showed that some key plasma biomarkers were significantly associated with the overall MedDiet and some relevant MedDiet components (37). In addition, the MedDiet intervention was associated with favorable, but modest, changes in markers of cardiovascular risk, specifically those related to lipid metabolism. Highlighting the overall well-known health effects of the MedDiet (38) and recognizing that the MedDiet can be a sustainable dietary pattern (39), more studies are trying to assess the metabolic signatures of adherence to the MedDiet, and although there are some common metabolites between studies, replication is limited. In this regard, we need to acknowledge varying results may be due to different identification methods (untargeted compared with targeted metabolomics) or biomarker assessment (NMR compared with MS coupled with gas- or liquid-phase chromatography), the use of different biological samples (urine, serum, or plasma), and nonstandardized statistical procedures. Thus, standardized processes such as data normalization, handling multiple testing, cross and external validation are of urgent need before results can be reliable (40). Fortunately, several joint collaborations are trying to overcome such limitations, and the Food Biomarkers Alliance (FoodBAll) has generated databases to identify and validate food intake biomarkers by gathering expertise among several fields (dietitians, clinicians, statisticians, chemists, etc.) and several countries (41).

Despite the growing body of research and evidence about the use of biomarkers and new omics technologies for diet assessment, there is still a lack of consensus among studies (42) and more research is needed before biomarkers can be used as a stand-alone diet assessment method. The combination of traditional methods with new methods can be a synergy strategy as we move towards nutrition for precision health. Although results from trials like the Personalized REsponses to Dietary Composition Trial (PREDICT) study (43) provide compelling evidence about the role of personalized nutrition and the gut microbiome and chronic diseases, it is essential to balance the individual versus broad population health impact of precision nutrition research.

Conclusion

Greater integration of technological advancements in diet assessment is critically important to better assess dietary intake as a multidimensional construct. Evidence regarding diet and disease relations generate benchmarks that inform implementation research that integrates biomedical and behavioral approaches into population-level prevention efforts and patient counseling in clinical settings. Furthermore, research on dietary quality emphasizes and supports the relatively recent paradigm shift in nutritional science toward focusing on dietary patterns instead of single nutrients or food groups. This shift may improve the validity of nutrition research studies and has clear implications for consumer behavior, dietary guidance, and food policy.

This commentary underscores the importance of addressing the limitations of existing dietary assessment methods by widely applying available technology to enhance traditional methods and by using multiple methods simultaneously to develop a comprehensive understanding of dietary quality and diet–disease relations.

Leveraging food acquisition and purchasing data represents novel, cost-effective sources of diet assessment and an objective metric of dietary quality. This addresses a critical issue related to health disparities and highlights how food procurement is influenced by access and availability in the broader food environment. Furthermore, determining the importance of processing level of foods when assessing dietary exposures is critical in better understanding diet and disease relations. Lastly, advancement in biomarker and -omics technology has the potential to dramatically enhance mechanistic understanding and variability in individual responsiveness to dietary patterns. Taken together, various advancements in diet assessment, particularly when combined, may be powerful tools for accurately characterizing diet–disease relations and shaping the food environment.

Acknowledgments

The authors' responsibilities were as follows—MKV and NP: were responsible for designing the manuscript; MKV, FJ, MSP, and NP: were responsible for writing the manuscript and take responsibility for the final content; and all authors: read and approved the final manuscript.

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