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COMMENTARY

Technology Innovations in Dietary Intake and Physical Activity Assessment: Challenges and Recommendations for Future Directions

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INTRODUCTION

Dietary intake (DI) and physical activity (PA) data are used in a variety of ways, including to determine nutrient adequacy and deficiency; to assess nutritional, fitness, and health status; to develop health promotion and behavioral interventions; and to understand food chemical and microbiological exposure, food–drug interactions, and pharmacokinetic effects.[1–3] Methods used to capture these data must therefore be reliable and accurate to ensure confidence when determining quantitative DI and energy intake (EI), food behaviors, and energy expenditure (EE), especially for real-time monitoring and interventions. Moreover, because the underlying pathways and mechanisms regulating energy homeostasis are not fully understood, improved measures can help address challenges in understanding interrelationships between DI and PA.

The increased prevalence of diet-related chronic diseases, obesity, and sedentary behavior has intensified interest to understand the long-term effects of diet and PA on aging and health. Although the use of biomarkers and new "omics" technologies has enhanced understanding of genotypic and biological effects, assessment of DI and PA has not progressed as rapidly.[4] Current DI and PA assessments are typically based on self-report and thus have inherent biases.[5–9] New technology-enabled methods designed to objectively measure DI and PA hold promise in addressing these shortcomings.

In 2016, NIH and the Interagency Committee on Human Nutrition Research intensified support to develop new objective tools to improve the accuracy and reliability of DI and PA measures.[10,11] An expert forum (Tech Summit: Innovative Tools for Assessing Diet and Physical Activity for Health Promotion) was convened at the University of California, San Diego (UCSD) in December 2016 to address the state of the science and technology innovations in DI and PA assessment across the life span. Scientists from the U.S. Department of Agriculture, Agricultural Research Service, American College of Sports Medicine, and NIH helped plan the program, and a multidisciplinary group of experts in the field discussed the current state of technology-enabled tools and methods for DI and PA assessment and identified challenges and future needs. Attendees comprised researchers, technology developers, commercial applicators, practitioners, ethics professionals, and policy makers from multiple disciplines, including statistical modeling, device development, software and biomedical engineering, nutrition and food sciences, behavioral sciences, psychology, sports medicine, biology, regulatory science, law, and ethics.

KEY LEARNINGS

Advancing Dietary Intake and Physical Activity Assessment Through Multidisciplinary and Cross-Sectoral Methods

Increasingly, data collection and application involves digital devices, big data, human subjects, and behavioral interventions expertise; thus, understanding across this range is seldom found in any one discipline. Scientists involved in DI and PA assessment come from many disciplines (e.g., computer science, behavioral sciences, and engineering) and sectors (e.g., industry, academia, and government). Moreover, they use such assessments for a variety of reasons, including research, commercial application, biomedical assessment and practice, counseling, and policy development. This diverse ecosystem combined with the wide versatility of data use, although beneficial, also raises new concerns and challenges. These

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include different approaches to (1) framing theories and hypotheses; (2) research study design and methods; (3) guidelines for ethical practices for informed consent, privacy protections, bystander rights, and data management protocols; (4) methods for data capture, processing, quality control, statistical modeling, and analysis; (5) data reporting, interpretation, and extrapolation; and (6) data translation for developing guidelines.

Because of this wide range of perspectives, the forum was specifically structured to share cross-disciplinary efforts on DI and PA assessment tools for EE and health status. The forum resulted in expert review papers on technology innovations in three age cohorts that are published concurrently with this commentary: "Advances and Controversies in Diet and Physical Activity Measurement in Youth";[12] "Dietary Intake and Physical Activity Assessment: Current Tools, Techniques, and Technologies for Use in Adult Populations";[13] and "Diet and Physical Activity Assessment and Interventions Using Technology in Special Populations: Older Adults."[14]

Convergence of Innovation Is Advancing New Tools

The rapid pace of development of new tools to measure DI and PA can be attributed to the convergence of innovation in several areas, including computational science, statistical modeling, device and software engineering, artificial intelligence, biomedical engineering, behavioral sciences, nutrition, and food science. This convergence has led to new technologies that support improvements in the quantitative, qualitative, frequency, and speed of DI and PA data capture and aim to enable improved understanding about how these data relate to both individual and population-level health outcomes.

Some of these improvements center on combining assessment tools to improve accuracy, such as biomarkers, omics, doubly labeled water for total EE, visual imaging, digital and smart devices, and interactive and wearable sensors for DI and eating patterns. Smart sensors placed at different positions on the body enable measurement of the event itself (e.g., chewing, swallowing, standing, or sitting). Along with new objective measurement tools, researchers are investigating innovations to further enhance analytic capacity involving big data analytics, computational modeling, statistical techniques to recalibrate data obtained from multiple sources, and artificial intelligence to capture behavior patterns and simulate individualized behavior.[4] Approaches and tools currently in place to measure DI and PA across the lifespan are discussed in this mini-review series. Although these innovations are promising, it is critical that the foundational work be done to establish whether these tools/strategies are acceptable, accessible, and easy to use by participants and consumers. Moreover, these technologies must be evaluated to ensure that they are accurate, cost effective, and produce valid and reliable data.

Incorporating New Science on Circadian Rhythms

Satchidananda Panda, PhD (Salk Institute), presented results of a scalable method using a smartphone (equipped with a mobile app, camera, and push notifications) to longitudinally monitor the effect of circadian rhythm on human food intake and fasting patterns.[15] This technology enabled the study of diurnal regulation of eating and fasting patterns, sleep−wake cycles, and their relation to metabolic function. Circadian rhythm regulation of behavior, physiology, and metabolism constitutes a large regulatory network that coordinates biochemical processes both within and between cell types. Most genes in mammals show tissue-specific daily expression rhythms. These rhythms sustain health by temporally separating incompatible processes, optimizing nutrient utilization, and coordinating interorgan communications. Therefore, factors that perturb or augment these daily rhythms may have a profound impact on health. Panda et al.[16] found that the daily feeding−fasting cycle sustains robustness of gene expression rhythms. In preclinical animal models, a robust feeding−fasting cycle without altering nutrient quality and quantity could prevent or reverse several chronic metabolic diseases, including obesity, insulin resistance, fatty liver disease, and dyslipidemia.[17] A human feasibility study revealed that daily rhythms in activity/rest and feeding/fasting may be erratic even among non−shift workers.[15]

KEY CHALLENGES

Energy Expenditure Assessment

Forum participants debated whether self-reports should be replaced altogether by a more accurate objective method in EE assessment. David B. Allison, PhD (Indiana University), presented the current challenges and debates in energy balance research. Of concern is the difficulty in measuring energy balance in humans outside of confined settings. Considerable evidence indicates that self-reports, the most common method for assessing EI in large-scale studies, are of such poor quality that some investigators have suggested the data not be used at all. Another issue is the lack of strong theory to reliably predict the extent to which energy compensation would occur in response to any perturbation of one component of energy balance in the short term. The absence of such a theory makes it challenging to generalize beyond any one setting or experiment with any confidence. Dr. Allison proposed options to move forward, such as establishing agreement that self-