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SPECIAL ARTICLE

Advances and Controversies in Diet and Physical Activity Measurement in Youth

Donna Spruijt-Metz, MFA, PhD,[1,2,3] Cheng K. Fred Wen, MPH,[3] Brooke M. Bell, BA,[3] Stephen Intille, PhD,[4,5] Jeannie S. Huang, MD, MPH,[6,7] Tom Baranowski, PhD[8]

Technological advancements in the past decades have improved dietary intake and physical activity measurements. This report reviews current developments in dietary intake and physical activity assessment in youth. Dietary intake assessment has relied predominantly on self-report or image-based methods to measure key aspects of dietary intake (e.g., food types, portion size, eating occasion), which are prone to notable methodologic (e.g., recall bias) and logistic (e.g., participant and researcher burden) challenges. Although there have been improvements in automatic eating detection, artificial intelligence, and sensor-based technologies, participant input is often needed to verify food categories and portions. Current physical activity assessment methods, including self-report, direct observation, and wearable devices, provide researchers with reliable estimations for energy expenditure and bodily movement. Recent developments in algorithms that incorporate signals from multiple sensors and technology-augmented self-reporting methods have shown preliminary efficacy in measuring specific types of activity patterns and relevant contextual information. However, challenges in detecting resistance (e.g., in resistance training, weight lifting), prolonged physical activity monitoring, and algorithm (non)equivalence remain to be addressed. In summary, although dietary intake assessment methods have yet to achieve the same validity and reliability as physical activity measurement, recent developments in wearable technologies in both arenas have the potential to improve current assessment methods.

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INTRODUCTION

Dietary intake (DI), physical activity (PA), and sedentary behavior (SB) measurement among children have experienced significant changes in accuracy and precision afforded by emerging new technologies. Even though technologies for measuring PA and SB have been available for over a decade and achieved notable accuracy,[1] pediatric DI measurement methods have substantial error,[2,3] and novel approaches to DI assessment continue to lack precision. Recent technological innovations in DI, PA, and SB measurement among children are the topic of this review. Although childhood is generally considered to involve individuals

From the [1]Center for Economic and Social Research, University of Southern California, Los Angeles, California; [2]Department of Psychology, University of Southern California, Los Angeles, California; [3]Department of Preventive Medicine, University of Southern California, Los Angeles, California; [4]College of Computer and Information Science, Northeastern University, Boston, Massachusetts; [5]Department of Health Sciences, Bouvé College of Health Sciences, Northeastern University, Boston, Massachusetts; [6]Department of Pediatrics, School of Medicine, University of California at San Diego, San Diego, California; [7]Rady Children's Hospital, San Diego, California; and [8]Department of Pediatrics, Baylor College of Medicine, Houston, Texas

Address correspondence to: Donna Spruijt-Metz, MFA, PhD, Center for Economic and Social Research and Departments of Psychology and Preventive Medicine, University of Southern California, 635 Downey Way, Suite 405, Los Angeles CA 90089. E-mail: dmetz@usc.edu.

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aged 2 through 18 years, what can be expected from the different technologies will vary by age of the child.

CURRENT METHODS TO ASSESS DIETARY INTAKE AND PHYSICAL ACTIVITY IN CHILDREN AND YOUTH

Alternative methods of DI, PA, and SB measurement are appropriate for different study designs, health purposes, and desired information. DI measures capture diverse elements (e.g., total caloric intake, specific nutrient intake, food groups, portion size, eating event, or bites taken). PA and SB measures also assess diverse elements (e.g., the type, duration, intensity, and sometimes location of PA and SB). Type typically consists of broad categorizations of PA and SB (e.g., ambulation, sleep) or specific types of activities or postures (e.g., walking, tennis, napping, cycling, or standing). Duration would ideally be measured throughout the entire 24-hour lifecycle[4] and across multiple days, weeks, or months, but usually that is not feasible. Intensity could be assessed in broad categories (e.g., moderate, vigorous) or as energy expenditure (EE) units over some period of time. Records (diaries), 24-hour recalls, and frequency questionnaires are the most commonly used self-reported assessment tools.[5,6] Self-report measures of DI, PA, and SB have significant accuracy (validity) and precision (reliability) limitations,[7,8] including recall or memory bias, participant burden, social desirability bias, and reactivity (i.e., the participant changes behavior to ease the burden or in light of the information).[9] Substantial bias (consistent underreporting) between self-reported energy intake and the gold standard of doubly labeled water (a measure of EE) have been demonstrated.[7] Although PA and SB assessment have progressed to more objective indicators of behavior (e.g., pedometers, accelerometers), these also have limitations. For example, wearable monitors worn on the hip do not detect upper body movement, or assess work (e.g., carrying weight), or posture (e.g., sitting versus standing). Sensors can be placed on specific parts of the body, such as on the thigh to detect posture,[10] but such special placement may increase participant burden, indicating a need for further innovative methods that minimize such constraints.

NEW DEVELOPMENTS IN BEHAVIOR MEASUREMENT IN CHILDREN AND YOUTH

Advances in DI, PA, and SB assessment have incorporated different forms of digital technology often in parallel, including: (1) computers in facilitating the self-report of behavior; (2) PDAs or smart phones for reporting and recording of behavior soon after it occurs (called Ecological Momentary Assessment [EMA]); (3) cameras in smartphones to take images primarily of foods (called "active" assessment because it requires initiation of the assessment and the use of image size markers, called fiduciary markers, by the participant); (4) wearable cameras that take images at short intervals (seconds) throughout the day (called "passive" assessment because no action needs to be taken other than putting it on and starting it at the beginning of the day); (5) various sensors, usually connected to some recording device; (6) integrated sensor and image methods; and (7) integrated sensor and behavior change intervention (Tables 1 and 2). Each technology is presented in sequence, first for DI and then for PA and SB combined.

Computers Facilitating Self-Report

Computer-assisted programs have been employed to improve the accuracy of the 24-hour dietary recall, including the Food Intake Recording Software System[37] and the Automated Self-Administered 24-Hour Recall (ASA24-Kids), adapted from the adult ASA24 system developed by the National Cancer Institute.[11] The ASA24 utilizes the Automated Multiple-Pass Method[38] to enhance accuracy and includes 20,000 or more images of foods, most in successively larger portions, to facilitate accuracy of portion size estimation.[12] To reduce participant burden, ASA24-Kids further eliminates elements, such as foods children do not commonly eat (e.g., quiche) and aspects of food preparation (e.g., added salt, fat content), most children cannot report.[13] Similar computerized systems have been developed for assessing children's DI globally (e.g., in Portugal,[39] Brazil,[40] and the United Kingdom[41]).

Although early procedures showed some improvement in categorizing foods[42,43] and portion size estimation,[44] methodologic challenges have also been reported. Comparison of recall data collected using Food Intake Recording Software System to criterion methods (e.g., direct observation) demonstrated a 35% intrusion rate (i.e., foods reported eaten, but were not) and a 15% omission rate (i.e., underreported foods eaten),[37] totaling to an approximately 50% food intake misidentification rate. Similar intrusion (27%) and omission (35%) rates were observed in studies that used ASA24-Kids, which were higher than a dietitian-administered recall (intrusions, 20%; omissions, 23%).[45] Inaccuracies in portion size reports have also been reported.[37] Unfortunately, ASA24-Kids is no longer available for general use on the National Cancer Institute website.

Ecological Momentary Assessment

EMA, an active real-time self-reported data collection technique that allows for flexibility in sampling time