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# A Primer for the Evaluation and Integration of Dietary Intake and Physical Activity Digital Measurement Tools into Nutrition and Dietetics Practice



Holly L. McClung, MS, RDN, LDN; Hollie A. Raynor, PhD, RDN; Stella L. Volpe, PhD, RDN, ACSM-CEP, FACSM; Johanna T. Dwyer, DSc, RD; Constantina Papoutsakis, PhD, RD

## BACKGROUND

**T**HE RISING PREVALENCE OF noncommunicable diseases (NCDs) is a global public health concern.<sup>1,2</sup> Unhealthy eating habits and physical inactivity increase the risk or severity of major NCDs such as obesity, coronary heart disease, diabetes mellitus, osteoarthritis, some cancers, and depression.<sup>3-5</sup> Primary prevention or treatments to combat NCDs include the adoption of a healthy diet without energy excess, routine physical activity, reducing sedentary time, and maintenance of a healthy body weight.<sup>6</sup> Technological innovations, such as digital measurement of DI and PA, have become widely accepted and are increasingly used to assess and monitor lifestyle behavior. Recently, the need for physical distancing because of the outbreak of the novel coronavirus (COVID-19), has revealed an additional urgent and dynamic use of valid and reliable technology in health care. Providers aspire that digital tools and telehealth platforms will help them to continue to provide health care even when face-to-face interactions with clients are imprudent or impossible. Delivering nutrition care in a framework of telenutrition continues to grow as the health care environment evolves and adapts.<sup>7,8</sup> However, whether increased demand for telenutrition will be supported by insurance coverage remains to be determined. Therefore, building a

structure for the appropriate use of technology is vital to provide effective nutrition care in the COVID-19 era.<sup>9</sup> While taking into account Standards of Practice and Standards of Professional Performance,<sup>10,11</sup> Registered Dietitians and Nutritionists (RDNs) and Nutrition and Dietetics Technicians, Registered (NDTRs), are uniquely positioned to play an active role in the development, use, and evaluation of DI and PA related technology for Medical Nutrition Therapy (MNT).<sup>12</sup> This type of work is part of the practice area of nutrition informatics.

Today, health care providers can transition from paper to digital-based tools for many measurement tasks. The explosion of mobile applications and wearables allows individual consumers to self-monitor their DI/PA, for their own purposes or for sharing data with their providers for subsequent evaluation and feedback.<sup>12</sup> In 2018, it was estimated that there were more than 160,000 mobile health applications to track DI/PA patterns, and over \$500 million was spent on these applications.<sup>13</sup>

The possibilities are endless. Software and application designers are focused on merging the needs of diverse users, providers, and consumers. For clinical researchers, the potential of big data aggregation and data mining hold promise and excitement in generating more accurate DI/PA captures of “point-in-time” and in developing more viable interventions with long-term benefits. In contrast, most consumers’ use of DI/PA technologies is aimed at self-monitoring, related to personal evaluation or awareness to maintain or change their

specific behaviors.<sup>14</sup> The technology should theoretically improve the efficiency and quality of data collection and facilitate attainment of all of these goals, and yet many questions remain about their use and acceptability. For example, because DI/PA assessment methods are often criticized as being inaccurate and imprecise, are the data from these new tools any more accurate?<sup>15</sup> Which tools are well-validated? Are there technologies that are available and appropriate for different populations, such as those of different ages or of different functional or cognitive capacities? Who owns the individual’s or group’s data once aggregated? What are the ethical/regulatory framework and steps needed to ensure anonymity and privacy? It is important to be aware of these factors when evaluating digital tools. A research priority of the Academy’s Research International and Scientific Affairs team is to support utility and application of emerging technologies, information management and knowledge management, processes to inform and advance nutrition and dietetics programming and practice. In this paper, the Academy’s Research International and Scientific Affairs Data Science Center and the International Life Sciences Institute North America’s (now the Institute for the Advancement of Food and Nutrition Sciences) working group on dietary intake and physical activity tools present essential information and perspectives on digital dietary intake (DI)/physical activity (PA) measurement tools. The goal is to provide emerging definitions used to describe digital technology in DI and PA measurement. Second, we describe

factors to consider when evaluating DI/PA measurement technology products as part of nutrition care. Finally, we delineate the outlook of digital DI/PA technology.

**Definitions for Health Care Technology Measurement Products**

Many terms are used to describe the intersection of health and technology. The World Health Organization has provided a large and detailed taxonomy of intervention terms for Digital Health.<sup>16</sup> Terms and definitions targeted to nutrition and dietetics professionals are provided below and in Figure 1.

A good starting point is a consensus framework proposed by four

organizations in the field of digital health: the Digital Medicine Society, Digital Therapeutics Alliance, HealthXL, and Health Network of Digital Evidence in Health.<sup>17</sup> The framework differentiates between products with different levels of clinical evidence, and degree of regulatory oversight. It classifies all types of digital health tools in three major categories: digital health, digital medicine, and digital therapeutics (Figure 2).

*Digital health* is very broad and includes all categories of health technology products such as mobile health (mHealth), health information technology, wearables, telehealth, and personalized health.<sup>18</sup> This category of products includes all applications that can be found in smart phone “app stores.” Digital health products do not

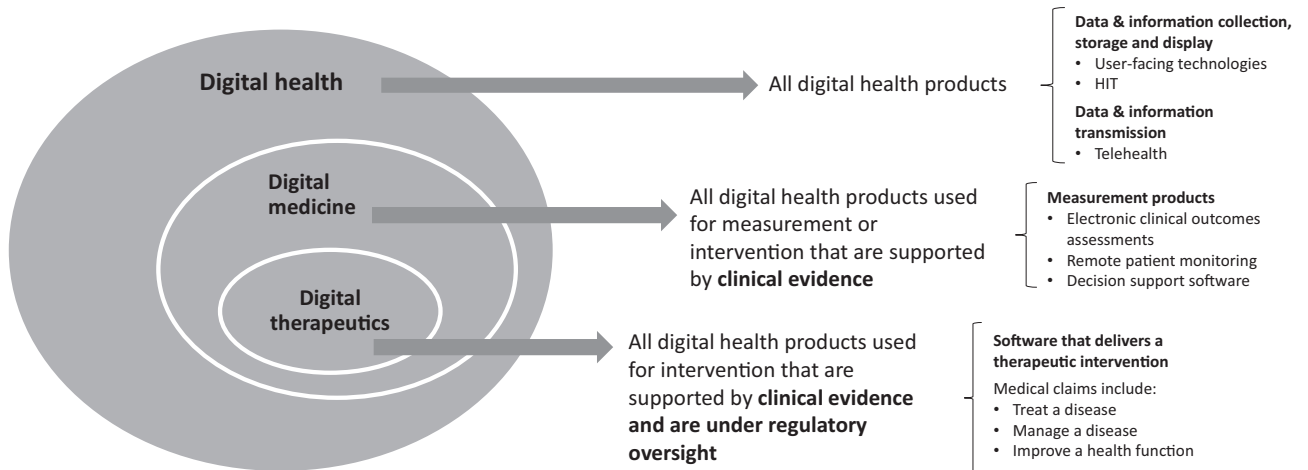
require evidence and do not require regulatory oversight (Figure 2).<sup>17</sup>

*Digital medicine* is a subset of digital health (Figure 2). The main difference between digital health and digital medicine is that digital medicine products must be backed by clinical evidence.<sup>17,19</sup> *Digital medicine* products are used for measurements or interventions aiming at health promotion, disease prevention, treatment, or recovery.

*Digital therapeutics* is a subset of digital medicine (Figure 2), because not all digital medicine products deliver an intervention. *Digital therapeutics* is defined as an evidence-based health technology product that delivers a health intervention and has been reviewed or certified by a regulatory body (most commonly the Food and

Term	Definition
Applications (apps)	Mobile applications used on a smart phone, tablet, or computer
Connected products <sup>70</sup>	Mobile technologies, wearables, ingestibles, implantables, and portable technologies with sensors for data collection
Devices <sup>71</sup>	A subset of lifestyle technology products with successful FDA approval for safety and effectiveness
Digital health <sup>18</sup>	Health technology products that <i>do not require</i> validity or efficacy or regulatory oversight
Digital medicine <sup>19</sup>	Health technology products used for measurement/intervention that are supported by evidence to demonstrate quality and validity
Digital therapeutics <sup>20</sup>	Evidence-based health technology products that deliver a health intervention and have been reviewed or certified by a regulatory body
Health information technology (HIT) <sup>72</sup>	Electronic medical records and related information systems
Image-based assessment <sup>73</sup>	Tools that rely solely on images using a camera-enabled smart phone, tablet, or computer to log food or activity
Image-assisted assessment <sup>73</sup>	Use of images in combination with another assessment method (eg, photos to supplement a written record or to proceed an oral recall in the office)
Telehealth or telemedicine <sup>74</sup>	Use of electronic information and telecommunication technologies to deliver and support long-distance clinical health care, patient- and professional health-related education, public health, and health administration
Telenutrition <sup>74</sup>	The interactive use, by an RDN, of electronic information and telecommunication technologies to implement the Nutrition Care Process with clients at a remote location (within provisions of their state licensure)
Wearable technology	General term for body-worn sensors capable of tracking location, time, environment, motion, and certain body measures (eg, blood glucose, etc.)
Web-based assessment	Tool requiring internet connection to log food or activity; often “cloud-based” data source

**Figure 1.** Health care technology measurement definitions. FDA = Food and Drug Administration, RDN = Registered Dietitian Nutritionist.



**Figure 2.** A Digital Health Framework; Adapted by the Data Science Center, Academy of Nutrition and Dietetics<sup>17</sup>. HIT = Health Information Technology.

Drug Administration [FDA]) for safety.<sup>17,20</sup>

**Evidence Supporting Digital and Therapeutic Medicine Products.**

Clinical evidence is required that demonstrates the products’ high quality and validity, for products to be classified as digital medicine or therapeutics. Thus, it is reasonable to ask: What type, amount, and caliber of evidence is required for a health technology product to qualify as a digital medicine or therapeutic product? There are no established or widely agreed-on criteria. Nutrition and dietetics professionals are encouraged to learn how and what digital tools to use and to conduct research demonstrating how digital tools complement MNT and improve health outcomes. These data are vital to support successful value-based reimbursements, especially as we navigate the COVID-19 era, in which effective use of technology may be integral in positive client outcomes and the future of the dietetics profession. Recently, an easy-to-administer tool on self-efficacy with using mobile health applications in dietetics practice was validated.<sup>21</sup> This tool may be a good place for the RDN to start a self-assessment exercise.<sup>21</sup> A later section focuses on choosing the best connected product, to provide guidance and reasoning in the selection process.

Digital technologies for DI/PA measurements are frequently described by the technology type used, and these may include online websites, mobile applications, camera-based tools,

wearable products, and others (Figure 1). The definitions that follow explain frequently used terms.

**Wearable Technology.** “Wearable technology” is any electronic product that can be worn as an accessory on the user’s body, embedded in clothes, implanted, or tattooed on the skin, typically to track information related to health and fitness (Figure 1). Common examples include step counters—smart jewelry such as rings, wristbands, watches, or pins. Smaller wearable technology typically connects wirelessly with a smartphone application for display and interaction. This term is not comprehensive because there are other technology products such as portable monitors, ingestibles, and so forth that are not necessarily worn on the body.

**Devices.** “Device” is a “term of art,” that is, a word with specific legal meaning used by the FDA. The term *device* refers to a small subset of lifestyle technology products approved by the FDA for a specific intended function (Figure 1). Whether a product is a “device” depends primarily on the product’s intended function as determined by the FDA’s Center for Drug Evaluation and Research’s review process. A product may be called a device once it has undergone successful FDA approval for safety and effectiveness. The FDA approval process is voluntary for manufacturers, but when it is successful, it works in the manufacturer’s best interest, because then the manufacturer can

make claims about the product’s intended use.<sup>22</sup> Claims can cover disease treatment (digital therapeutics that deliver a medical intervention to treat a disease), disease management (digital therapeutics that deliver a medical intervention to manage a disease), or improving a health function (digital therapeutics that deliver a medical intervention to improve a health function or prevent a disease).

**Connected Products.** Connected products are those with a real-world function that are connected to the internet to transmit data or are controlled remotely. This comprehensive term includes mobile technologies, wearables, ingestibles, implantables, and portable technologies that have sensors (Internet of Things) for the collection of outcomes data (Figure 1). Connected products can connect with each other and with other systems via the internet, and they can share data about themselves, their environment, and their users. The range of connected products is ever expanding, from cars to medical equipment (such as continuous glucose monitors), industrial machinery, and even packaging that is capable of reporting the location and condition of packaged food or other commodities.

**Is There a Role for Connected Products in Nutrition Care?**

Instead of episodic measures collected at client visits, connected products provide the practitioner with longitudinal, and potentially more

comprehensive, “real world” datasets for DI/PA, which the Clinical Trials Transformation Initiative and other expert groups consider to be more valuable.<sup>23</sup> Connected products may create a digital virtual “twin” of the client that captures data that historically have been difficult to collect. Intermittent collection of 24-hour dietary recalls or food records provide single or only a few representations of DI, whereas a connected product may potentially record DI around the clock for long periods. Such around-the-clock monitoring provides a more accurate picture of the targeted behavior in the client’s life and greater awareness of it. Conventional 24-hour dietary recalls and food records are frequently criticized for inaccuracy.<sup>24,25</sup> Some studies suggest that data capture by digital means are more complete. For example, an online 24-hour dietary recall (myfood24) for dietary assessment provided higher-quality DI data than standard interviews when compared with biomarkers.<sup>26</sup> Furthermore, an electronic 12-hour dietary recall was superior in assessing DI than either a food frequency questionnaire or 4-day food records.<sup>27</sup> In energy expenditure, the reference standard method is indirect calorimetry, which is not easy to use routinely in clinical care. Also, with inpatient energy estimates using visual estimation of food amounts eaten, there is a high probability for human error. There are different validated connected products that provide a practical alternative to indirect calorimetry and inpatient energy estimates for different populations.<sup>28-31</sup>

### What Does the Evidence Show on the Efficacy of Connected Products?

Digital tools may have a beneficial impact on health-related interventions, particularly in the areas of self-monitoring of DI/PA. However, to be effective, these tools must keep track of the user’s progress toward achieving the targeted DI/PA goals, improve adherence to the targeted behavior while minimizing respondent burden. Self-monitoring of DI/PA are important components of lifestyle interventions such as treatment of overweight and obesity. A systematic review on self-monitoring of DI/PA during weight

loss interventions described the efficacy of self-monitoring on weight loss (primarily paper-based tools used).<sup>32</sup> In that review, 22 studies were included, with 15 reporting on self-monitoring of DI, one reporting on self-monitoring of PA, and six reporting on self-weighting and weight loss. For DI self-monitoring, all 15 studies reported a significant relation between self-monitoring and weight loss. Of the studies examined, four explored the quality of DI self-monitoring that was associated with weight loss. More comprehensive self-monitoring (ie, captured more eating occasions throughout the day) and regular self-monitoring (ie, more days of the week) was related to a greater weight loss.<sup>32</sup> Related, Carels et al<sup>33</sup> investigated self-monitoring of PA (paper-based) and also reported that greater self-monitoring was associated with higher frequency of PA ( $r = 0.52$ ,  $P < 0.01$ ) and greater weight loss ( $r = 0.44$ ,  $P < 0.05$ ).<sup>33</sup>

With respect to the integration of technology into lifestyle interventions, the impact on enhancing self-monitoring of DI was directly examined within a 24-month weight loss trial.<sup>34</sup> Paper-based self-monitoring was compared with self-monitoring on a personal digital assistant (PDA) in 210 adults. Although the PDA was not connected to the internet, the Dietmate Pro software had automated capabilities to calculate DI for energy and nutrients consumed for point-in-time diet self-monitoring. Investigators compared three conditions, paper diary, PDA, and PDA+feedback (FB). In PDA+FB, additional feedback software was used to interact with Dietmate Pro via a custom algorithm to provide tailored daily messages to the participant concerning DI in relation to dietary goals. Although there was no significant difference in weight loss between the conditions at 24 months, those who self-monitored with the PDA (PDA and PDA+FB combined) had significantly better adherence to self-monitoring (defined as the percentage of days that at least 50% of the daily energy goal was recorded) than the paper diary condition. Across all participants, better adherence to self-monitoring was significantly related to greater weight loss ( $P < 0.001$ ). A weight loss of at least 10% was measured for those with  $\geq 60\%$  self-

monitoring adherence regardless of intervention tool used.

More technological advances in dietary self-monitoring have occurred since then. However, few researchers have examined the efficacy of technology-based dietary self-monitoring vs paper-based dietary self-monitoring on weight loss outcomes. Because self-monitoring with paper-based systems is known to have flaws, it has often been assumed that real-time technology-based dietary self-monitoring will address some issues by invariably enhancing outcomes compared with paper-based dietary self-monitoring.<sup>32,35</sup> Therefore, there has been more research on which components of technology-based dietary tools should be used to enhance self-monitoring adherence and weight loss outcomes. Mobile applications provide various electronic forms and interfaces to assist in logging DI (ie, text, photos) with capabilities to provide multiple reports/summaries of intake (ie, text, graphs). There is considerable research on identifying which components of the technology-enhanced method are ideal for promoting self-monitoring.<sup>36</sup> For example, Dunn and colleagues<sup>37</sup> examined a mobile photo dietary self-monitoring application to a calorie tracking DI self-monitoring application on self-monitoring frequency and weight loss in 41 adults receiving a remotely delivered 6-month lifestyle intervention.<sup>37</sup> Outcomes were similar between the tools used over the number of days the diet was logged (defined as logging at least one food or beverage item). Overall, reported logging was low across all participants ( $<30\%$  of days), but logging was significantly related to greater weight loss across all participants ( $P < 0.001$ ), and it was actually improved among those using the calorie tracking DI self-monitoring application ( $P = 0.004$ ), with no significant difference compared with those using the mobile photo DI self-monitoring condition ( $P = 0.06$ ). Significant weight loss occurred across the 6 months, but weight loss was not different between the conditions. Thus, which method of technology-based DI self-monitoring may enhance efficacy in weight loss, or whether technology-based self-monitoring enhances weight loss outcomes compared with paper-based self-monitoring, is unclear at this time.

- **Accuracy**
  - Validation studies (technical, clinical, systems)
- **Intended use**
  - Measurement of the desired variable
  - Appropriate for length time
  - Automation as required
  - Flexibility across platforms
- **Target population**
  - Cultural acceptability
  - Age group (acceptability and feasibility, and level of interest)
  - Related conditions that can influence usability or benefit (clinical suitability)
  - Literacy and numeracy skills
- **Cost (in relation to system, client, value-based reimbursement)**
- **Ease of use (user experience or UX)**
  - User friendly
  - Easy access
  - Use across technology platforms
  - App features can be tailored
  - App offers a platform for health care professionals to access data (this provides a way to track, observe,

facilitate engagement) (two-way communication)

- **Transparent data use, ownership, and privacy**

**Client uses the app effectively!**

DI/PA data are informative and actionable

Generated data contribute to improving behavior change, care, and practice patterns

Safe experience

*(continued on next page)*

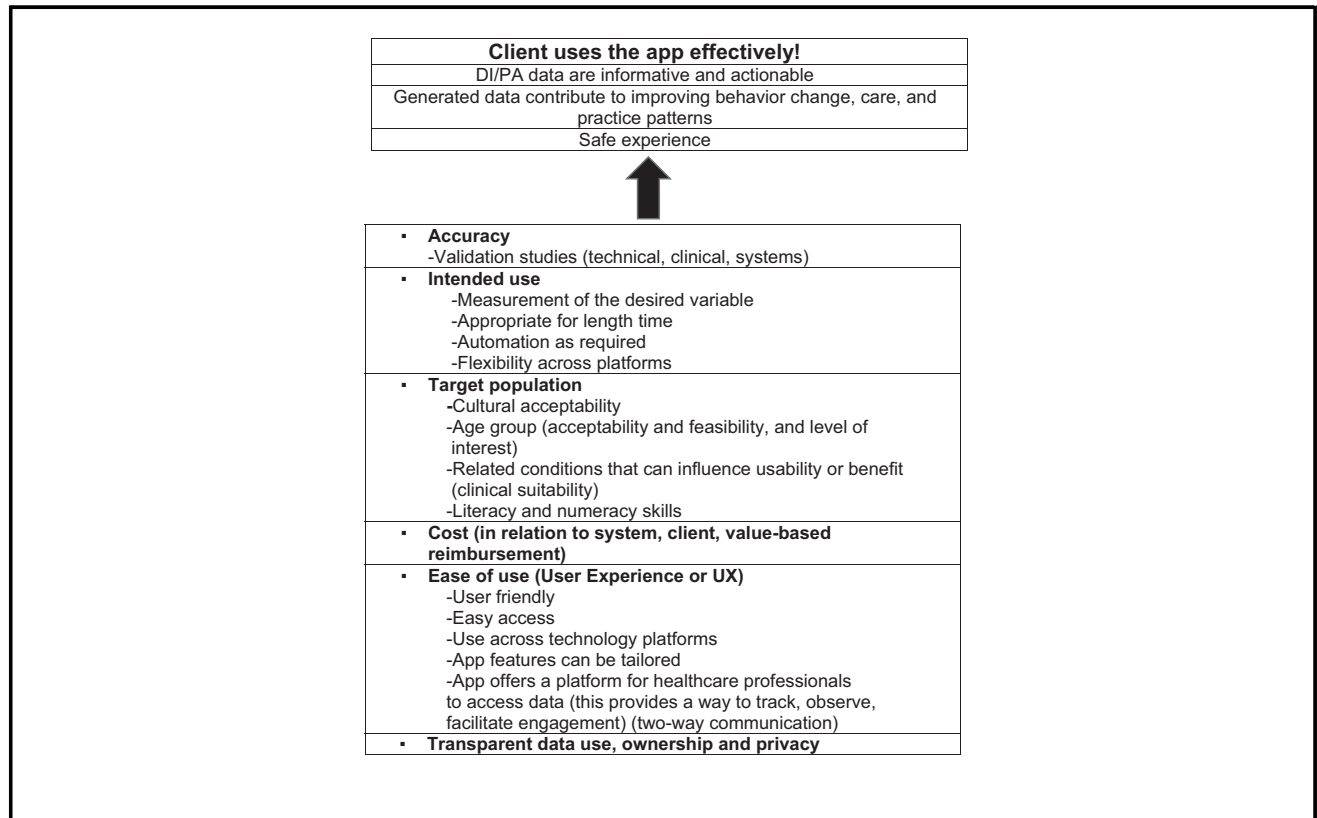
**Figure 3.** Important factors for RDNs/NDTRs to consider when selecting an app and desirable outcomes. DI/PA = Dietary intake/physical activity.

Similar to the situation with DI self-monitoring, research is lacking to examine the efficacy of technology-based as compared with paper-based PA self-monitoring on weight loss outcomes.<sup>38-41</sup> A systematic review published in 2018 examined the effect of wearable activity trackers on adherence and weight loss outcomes when the trackers were included as part of an obesity treatment program.<sup>42</sup> This review included 25 studies using portable devices to track PA via step count, heart rate, and energy expenditure for weight loss. Studies varied greatly; some included programs without PA goals, others had programs that only focused on PA, and some had no intervention at all. Because of incongruent methods of tracking attrition, the authors could not make overall conclusions regarding the effect

of wearable activity trackers on adherence. Eighteen studies with middle-aged and older participants reported greater weight loss outcomes when an activity tracker was part of a weight loss program.<sup>42</sup> Three studies with younger adults did not find this relationship.<sup>42</sup> Thus, the authors concluded that short-term (<6 months) weight loss interventions using activity trackers may improve weight loss outcomes in middle-aged or older adults.<sup>42</sup> A new systematic review on older adults (>55 years) corroborates improvement of PA in the short term when using a PA mobile application.<sup>43</sup>

A 2017 meta-analysis examined the effects of wearable activity monitors on improving PA and weight-related outcomes. Included studies were randomized controlled trials in which one condition used a wearable activity

monitor that was not a pedometer (ie, measured vertical acceleration movement while providing feedback), and outcomes of PA or weight had to be reported at 3 months or later.<sup>39</sup> Comparative conditions included inactive (no active intervention) and active interventions. Unfortunately, adherence to self-monitoring of PA was not reported. Fourteen studies were included in the analysis, 12 of which reported on PA and 11 on weight outcomes. For PA, the overall pooled estimate indicated a small, statistically significant effect, in which wearable activity monitors increased PA (standardized mean difference = 0.26; 95% confidence interval [CI] = 0.04–0.49). For weight loss, the pooled estimate also indicated a small, statistically significant effect (mean difference = –1.65 kg; 95% CI = –3.03



**Figure 3.** (continued) Important factors for RDNs/NDTRs to consider when selecting an app and desirable outcomes. DI/PA = Dietary intake/physical activity.

to -0.28). These results, combined with the results of the 2018 systematic review by Cheatham et al,<sup>42</sup> support that wearable activity trackers can be helpful for weight loss, but the effect sizes are rather small.<sup>39,42</sup>

Taken together, research in this area suggests that self-monitoring of DI/PA is related to weight loss outcomes, when self-monitoring is a component of a weight loss intervention. What is not clear at this time is whether technology-based self-monitoring, compared with paper-based self-monitoring, enhances efficacy of provider-led obesity treatment programs, and what type of technology-based self-monitoring might enhance outcomes. In practice, what is important to recognize is that self-monitoring of DI/PA enhances treatment efficacy. Which type of self-monitoring enhances treatment efficacy is not clear. Thus, factoring in individualized client preference for type of self-monitoring, paper-based vs technology-based is important. If technology-based self-monitoring is preferred, RDNs are encouraged to carefully evaluate what

kind of technology-based self-monitoring would be optimal. Beyond client preference, another important factor for practitioners to consider regarding self-monitoring is whether the self-monitoring strategy tracks the area in which goals have been set. For example, if the goal is focused on increased fruit and vegetable intake, then the tool must be able to track cups of fruit and vegetable intake as an output. Although paper-based self-monitoring can be easily adapted to goals, not all technology-based self-monitoring tools have the capability to track all DI or PA goals and may not be adaptable to all potential goals. This requires the practitioner to be familiar with a variety of tools to “custom-fit” to the client and the client’s outcome goals throughout the phases of treatment.

**Selecting the Best-Connected Product**

The process of selecting a technology or tool that fits best should focus on user or provider preferences and limitation of barriers that are unique to the

particular circumstances of use. In the selection process, three key factors should be considered: level of accuracy required (eg, research- or client-focused need); intended use (eg, baseline assessment, intervention monitoring, and so forth); and target population (Figure 3).<sup>15</sup> However, even with these factors in play, settling on the “right-fit” DI/PA technology to provide real value to the RDN and client can be a challenge among the cluttered landscape of new technologies.

In 2019, Eldridge et al<sup>44</sup> led an expert group to review 43 new DI assessment technologies aimed to provide guideline criteria for future tool assessments and offer standardized reporting recommendations.<sup>44</sup> This report compares and contrasts between research- and consumer-designed technologies (reported in literature from 2011 to 2017) over 25 attributes for evaluation, including methods to validate the technologies (eg, energy intake compared with total energy expenditure from doubly labeled water or traditional dietary assessment).

Validation studies were more likely to be reported for research-facing DI technologies than those targeted to consumers.<sup>44</sup> This raises the question about what preferences are the focus when selecting a technology—is the “fit” provider- or user-based? A recent study surveyed 1,001 international health professionals (eg, RDNs, nurses, and physicians) of which approximately 45% (of these, 50% were RDNs) had previously recommended DI application use to clients.<sup>45</sup> The primary factors influencing DI application choice by providers were ease of use (87%), free of charge (73%), and validated technology (69%). Providing a client with new technology that is *user-friendly and easy to access* on the client's personal device is key to promoting long-term use and acceptance in self-monitoring. Both are relatively easy for the provider to determine, but finding a valid and trusted connected product is a much more complex issue for the provider.

Digital health technologies require a robust and transparent validation process that should encompass three domains: technical (eg, how accurately does the tool measure?), clinical (eg, does the tool have support to improve health-specific outcomes?), and systems (eg, does the tool integrate into a client's life, provider workflow, and health care system?).<sup>46</sup> Few research-based technologies provide information on technical validity with respect to data accuracy and software limitations, and even fewer provide information to support clinical and system validation.<sup>47</sup> New technologies and tools in DI/PA assessment show close agreement to traditional methods, but wider gaps are evident when they are compared with more objective measures (eg, total energy expenditure from doubly labeled water).<sup>44</sup> Current DI technology validation research focuses on comparisons with traditional DI assessment methods (eg, 24-hour recalls, food records, food frequency questionnaires, and so forth).<sup>48</sup> Ideally, in the future, developers and researchers will include more objective criteria measures (eg, doubly labeled water, biomarkers, and so forth) to compare new technologies and publish the detailed evaluation of validity work.<sup>15,45</sup> A handful of technologies

show promise in specific age groups, or over particular spans of time, and some are considered accurate under only specific activities.<sup>49</sup> For example, a systematic review of 67 studies compared use of Fitbit vs a research-standard criterion and consistently found that Fitbit devices were only likely to be accurate for step count 50% of the time when used in an adult population.<sup>50</sup> Findings suggest that Fitbit has a tendency to underestimate steps in a controlled setting and overestimate in a free-living setting. Additionally, Fitbit is not likely to provide accurate measures for total energy expenditure under any condition, but it provides a measure similar to accelerometers to capture the amount of time spent doing lower-intensity activities, such as sitting or sleeping.

A common thread evident throughout current DI/PA technology measurement research is the lack of standardization and transparency in the validation process. In the United Kingdom, a consortium has been established among the technology industry, researchers, clinicians, and regulatory agencies to provide users and health care providers with a library of currently available and validated health applications. The National Health System Apps Library is the largest health website in the United Kingdom with a section specifically devoted to reviewing applications.<sup>51</sup> The National Health System Apps Library currently features approximately 100 applications that have been validated by experts from technology, health care, and policy backgrounds. Application developers self-nominate their technology to be featured in this library by completing an assessment that covers national standards, regulations, and industry best practices to gauge how the technology performs against important criteria. The greater the effectiveness potential of the application, the more complex the assessment. A similar trusted peer-reviewed resource in the United States would be highly beneficial and is sorely needed.

The intended use of a technology needs to be strongly considered before down-selection of the “right-fit” tool by the provider. Consideration must be given to the *length of time* the

technology will be used by a client. An application or technology used for a short-term baseline assessment may warrant different standards and efficiency from a technology to be used for long-term or regular monitoring for maintenance care or intervention. *Automation* of DI or PA logged activities by the user into useful numerical values for assessment and feedback by the provider may be preferred over longer use periods because of the sheer amount of data collected.<sup>52,53</sup> Another area to evaluate is the *flexibility of a technology across platforms* (eg, Android vs iOS) to allow compatibility with a user's mobile device. With this, the provider must have a detailed understanding of how personal data will be stored and shared (with the provider and across the software designer). Ideally, an open access software platform and structure allows insight as to *data use and privacy*. Some current technology and applications available have research-grade options of the software available for use in a private setting, with user-defined controls in output and data ownership.<sup>44</sup>

Mobile devices with health applications create new opportunities and risks to the user and provider or researcher. More data than ever are collected in a streamlined and simplified process from smartphone hardware and sensors, and then with the addition of secondary mobile devices to expand the platform to application-navigated health devices (eg, glucose meters, heart rate monitors, pulse oximetry, and others).<sup>54</sup> Applications that can be tailored to the client's needs or allow two-way data flow between provider and client may result in improved outcomes.<sup>55</sup> Data sharing requires clients to opt in so that the provider has ongoing access. Applications that come with platforms for providers facilitate two-way communication, provide a benefit of seamless monitoring, and support engagement between provider and client. Research conducted using many new health monitoring technologies is “unregulated,” meaning it is not covered by federal research regulations and is not referred to an Institutional Review Board, unless the technology has been approved as an FDA device. The regulatory oversight of connected products



is evolving. Since the 21<sup>st</sup> Century Cures Act,<sup>56</sup> the specific role and involvement of the FDA is being more rigorously explored.<sup>57</sup>

There is concern that widely used technologies in “unregulated” research are unethical, result in low-quality data, and are possibly exposing participants to harms ranging from privacy violations to psychological and physical injury.<sup>58</sup> Extending federal research regulations to cover all research with human participants would be the most effective way to address the issue. However, this may not be a viable option in the immediate future. Therefore, recommendations to protect clients include best practice measures monitored by government (state and federal), the technology industry itself (application designers), and researchers to include education, consultation, transparency, self-governance, and regulations to cover basic research ethics.<sup>58</sup>

A favorable user experience (frequently abbreviated as UX) has the potential to improve overall usability of the application. Providers should look for products that provide ease of use and have been developed in accordance with industry UX standards. A key consideration in selecting technologies for use is matching the *target population* to the intended tool. Choosing a technology that “fits” both the user and provider not only provides a more valuable output; it is instrumental in the longevity of technology use and potential to impact the health outcomes of the client. *Cultural acceptability* must be considered so that food items and activities align well with the target population. *Clinical suitability* is also important. When working with clients with disordered eating or body image disturbances, it may be important for the application to allow a provider to “turn off” numerical values to the user while the clinician uses them for tracking DI/PA to aid in interventions.<sup>45</sup> It is also important to consider *acceptability and feasibility* when dealing with young children, older adults, or those with limited literacy and numeracy skills. There are several factors to consider in these populations. For a full discussion on modern considerations in a pediatric population, refer to Spruijt-Metz

et al.<sup>59</sup>; and for older adults, Takemoto et al.<sup>60</sup> Because of the growing number of older adults seeking DI/PA interventions, we describe here many barriers that might be encountered; others also may be pertinent. Individuals with vision problems may find it difficult to see the small screens on mobile devices such as smartphones and smartwatches. Physical limitations such as arthritis, tremor, and other tactile problems may make it difficult to touch and activate screens or keys successfully. Few devices have audio options that can overcome this limitation. Cognitive deficits may make record keeping difficult or impossible. Data interpretation and acceptability barriers in addition to habits and potential lack of economic resources may lead some older individuals to not owning personal mobile devices or computers, or if they do, they may not use them often.<sup>60</sup>

### Unintended Health Consequences

There are unintended health consequences in using digital technologies that need to be considered. For example, tracking applications have been reported to intensify behaviors related to disordered eating. In a recent study, self-use of energy consumption tracking applications were associated with disordered eating patterns such as increased eating concern, and dietary restraint, but not with shape and weight concerns.<sup>61</sup> Thus, individuals using energy tracking applications may be doing so for reasons unrelated to body satisfaction. In the same study, PA tracking was related to eating disorder symptomatology, which may be of concern. Use of Instagram, a photo and video-sharing social media platform, was associated with orthorexia nervosa, a behavior characterized by the obsessive pursuit of eating a healthy diet.<sup>62</sup> Although the literature is quite limited, available results suggest that, for some people, connected products may exacerbate propensity to disordered eating behaviors.

Health-related harm also may be involved when the measurement of a connected product is not accurate, potentially jeopardizing health. In general, DI/PA connected products

likely do not pose overt health risks by miscalculation in the measurements themselves. However, a systematic review of 46 applications calculating insulin dosing by leveraging data from planned carbohydrate intake among persons with diabetes mellitus showed that two-thirds of them calculate incorrect insulin doses.<sup>63</sup> Such erroneous measurements may put individuals at health risk for suboptimal glucose management or other undesirable health consequences. RDNs are uniquely positioned to counsel clients appropriately to ensure the choice of tools is a good fit for the health problem in question and specific to the client.

### Digital Technologies as Adjuncts to Nutrition Care

Digital technologies are adjuncts to, rather than substitutes for, the effort of RDNs in crafting effective behavior change programs involving nutrition care.<sup>64</sup> RDNs may match clients with tools that are a valid, reliable, and acceptable fit. RDNs are health care professionals who synthesize DI/PA data, with other important and relevant variables identified in nutrition assessment, to prioritize and address effectively their clients’ nutrition problems.<sup>65,66</sup> For example, step counters and digital reminders are useful adjuncts to a weight loss program that includes group meetings, weigh-ins, or nutrition counseling. If the rest of the program is abandoned, effectiveness may be lost. As trained professionals, RDNs/NDTRs leveraging their expertise and critical reasoning to design/select/use technology to track and improve clients’ DI/PA are necessary to achieve health outcomes for clients.<sup>67</sup> In a recent international survey on the use of diet applications in health care that invited providers to participate, 833 dietitians from 73 countries reported application usage and experiences in provision of care, and this comprised more than 80% of the survey sample. Physicians and nurses ranked next in frequency participation (in the range of 6% to 7% each).<sup>45</sup> Nutrition and dietetics professionals around the world are learning, using, and applying DI/PA applications to best reap the benefits for clients.<sup>68</sup> It will be important to

study the use of applications in measuring DI/PA with and without the facilitation of trained providers (ie, RDNs/NDTRs) to understand the differences and potentially emerging consequences in health outcomes.

## OUTLOOK/CONCLUSION

The growth of digital health DI/PA technologies is exponential. Health care providers must keep pace with new methods and tools, because increasing evidence suggests that self-monitoring improves health outcomes across noncommunicable diseases. New technologies offer the potential to monitor DI/PA over longer periods with more efficiency and potentially greater impact. Providers' goals should be, first, to provide clients individualized tools and methods that are valid, reliable, acceptable, and second, to help them use the tools appropriately as part of an MNT plan of care. However, the current state of the DI/PA technologies lack standardization and transparency in validation, privacy, and sharing of data. Together with other health care providers, we need to insist on improvement in the regulation of health technologies to protect our clients and advance the nutrition and dietetics profession. The future of DI/PA technologies would benefit from a "health-centered design," an approach that would function to bridge the gap between provider/client wants and developers' products.<sup>69</sup> In addition, "people-centered design" is needed where products are developed, tested, and updated with both providers and clients in mind (and with input from these audiences). Such an approach would engage providers, clients, and application/device designers throughout the technology product development and gracefully integrate technology into routine health care. A comprehensive electronic platform that rigorously evaluates available DI/PA applications in real time is a much-needed resource. Overall, RDNs/NDTRs and other health care professionals must work to align and improve the design of technologies to not just assist but optimize nutrition care across the board. Future technology will benefit from greater engagement among developers, RDNs/NDTRs, or targeted patient groups to improve UX (user experience) and usability. More

attention is needed to applying behavior change theory in technology development. Digital measurement tools also need to be using more plain language and reflect health literacy, especially when it comes to any messaging that is provided so that different target populations benefit in an inclusive fashion. Integrating technology into routine nutrition care, and showing related efficacy, may be the way forward for successful value-based reimbursements, especially as we navigate in the COVID-19 era.<sup>64</sup>

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## **AUTHOR INFORMATION**

H. L. McClung is a nutritional physiologist, US Army Research Institute of Environmental Medicine, Natick, MA. H. A. Raynor is a professor, Department of Nutrition with the University of Tennessee Knoxville, Knoxville, TN. S. L. Volpe is a professor and department head of the Department of Human Nutrition, Foods, and Exercise, Virginia Polytechnic Institute and State University, Blacksburg, VA, and a Board Member of the Institute for the Advancement of Food and Nutrition Sciences (formerly the International Life Sciences Institute (ILSI) North America). J. T. Dwyer is a professor of Medicine, Tufts University School of Medicine, senior scientist Jean Mayer USDA Human Nutrition Center and Director, Frances Stern Nutrition Center, Tufts Medical Center, Boston, MA, and a scientific advisor to the Institute for the Advancement of Food and Nutrition Sciences (formerly the International Life Sciences Institute (ILSI) North America). C. Papoutsakis is a senior director, Nutrition and Dietetics Data Science Center, Research International and Scientific Affairs with the Academy of Nutrition and Dietetics, Chicago, IL.

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## **AUTHOR CONTRIBUTIONS**

H. L. McClung, H. A. Raynor, J. Dwyer, and C. Papoutsakis wrote different components of the initial draft of the article. All authors conducted critical revisions, reviewed, and commented on subsequent drafts of the manuscript.