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Feasibility of Using Participant Owned Smartphone Features to Conduct Ecological Momentary Assessment of Planned Exercise Behavior in College-Aged Adults

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Cover Page Footnote

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INTRODUCTION

Regular aerobic physical activity and/or exercise reduce the risk of developing non-communicable disease (ODPHP, 2018), yet many adults are insufficiently active (Troiano et al., 2008). Physical activity and exercise behaviors are complex, dynamic, and can be influenced by a variety of contextual, perceptual, cognitive, and affective factors, which may fluctuate considerably over time within an individual (Dunton, 2017; Dunton, Atienza, Castro, & King, 2009). With the goal of developing personalized interventions, it is increasingly important to empirically quantify and describe the complex interplay between such factors and activity behaviors of individuals in the free-living environment. As technology advances, the use of ecological momentary assessment (EMA) is becoming more prevalent to understand relationships between time-varying factors and health behaviors (Shiffman, Stone, & Hufford, 2008).

EMA refers to repeated, real-time sampling from individuals in their natural surroundings (Shiffman et al., 2008). In-the-moment reports purportedly reduce inaccuracies due to recall bias, social desirability, or mood-dependent memory. Thus, implementing EMA accurately and with minimal burden is a critical aspect to research design. Early studies have shown success in conducting EMA via personal digital assistants (PDAs) (Gwaltney, Bartolomei, Colby, & Kahler, 2008). Compared to pen-and-paper diaries for time-series data collection, the use of PDAs pairs the signal prompt and survey in one device (Green, Rafaeli, Bolger, Shrout, & Reis, 2006; Gwaltney et al., 2008; Stone & Shiffman, 1994), with time stamps to verify that data were collected within targeted time frames. With declining ownership of PDAs, their use may add burden to researchers and/or participants (e.g., purchasing devices, familiarization, remembering to carry and charge it).

A promising approach to collect time-stamped EMA data is using participant-owned smartphones. Nearly 80% of Americans own a smartphone, with this percentage rising to 94% for those between the ages of 18-29 (Pew, 2016). Regarding usage, 90% of cellphone and smartphone owners indicate that they “frequently” carry their device and 76% indicate they never or rarely turn it off (Pew, 2015). We are particularly interested in utilizing short message service (SMS; text messaging) in conjunction with Internet capabilities to disseminate surveys for EMA of exercise behavior, as these represent two of the most frequently used features (Pew, 2010). To our knowledge, only one recent study (Ehlers et al., 2016) assessed the feasibility of using both features to assess self-worth and physical activity in middle-age women. In order to expand this literature, the purpose of this brief report is to summarize feasibility outcomes from a parent study that used SMS and Internet smartphone features to conduct EMA (14-d) of planned exercise behavior in a sample primarily consisting of undergraduate and graduate students.

MATERIALS AND METHODS

Participants

All procedures were approved by the university Institutional Review Board and all participants provided written informed consent. Data were collected from June-November 2016. Participants were included if they 1) were at least 18 years old, 2) were not currently involved in varsity sports, and 3) owned a smartphone with SMS and Internet capabilities. Of the 30 individuals initially enrolled, 29 completed the study, with one participant requesting to withdraw within the first two days. One participant was pushed into a pool after 1:30pm on day 12, preventing further data collection. On average, participants were young adults, (24±6 years, 55% women, 76% white) and reported an average of 1116±596 MET-minutes of exercise per week.

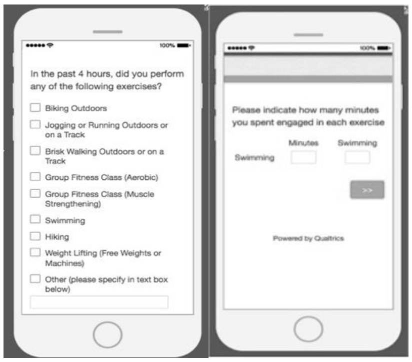
Instrumentation

Participants' smartphones were tested to verify text and Internet capabilities with a sample survey sent through the Qualtrics Research Suites platform (Provo, UT). One person (AT&T customer) needed to contact his provider to unblock short code messages. Survey distribution was designed to achieve coverage of waking hours (9:30am, 1:30pm, 5:30pm, and 9:30pm) across 14 days. Each SMS contained an active link to open the survey in an Internet browser. Surveys completed within 60-min of receipt were considered valid.

In each survey, respondents were asked if they had engaged in planned exercise over the prior four hours. If yes, respondents indicated exercise mode(s) and duration (Figure 1). Each survey included 26 additional items relevant to the parent study regarding hypothesized antecedents of exercise (e.g., affective states, stressful events, exercise self-efficacy).

An ActiGraph GT3X+ accelerometer (ActiGraph LLC, Pensacola, FL) was concurrently used to objectively measure physical activity. The sampling rate was set to 30 Hz, which provided the longest battery life and greatest memory limit for this device. Participants were instructed to wear the device on the anterior axillary line of the right hip during all waking hours, with a minimum goal of ≥10h/day, in line with standard criteria for a valid day (Troiano et al., 2008). Participants were also given a pen-and-paper log to indicate wear-time.

***Figure 1*. Ecological momentary assessment items to assess exercise type and duration**



Procedures

Following eligibility screening, consenting participants were familiarized with a mock version of the survey, with explicit instructions to only report exercise (i.e. planned, structured activity intended to improve one or more aspects of physical fitness), as opposed to general physical activity (e.g., active transport, heavy chores). Individuals were given their accelerometers and wear-time logs. SMS prompts began the following morning. The first follow up visit (~7 days) was used to determine initial compliance. Participants presenting with less than 75% survey completion and/or less than 10-h of accelerometer wear time per day were verbally encouraged to improve compliance. The final visit occurred within 48-h of day 14. All participants who completed the study, regardless of compliance, were compensated for their time with $20 in gift cards to a local grocery chain.

Data Processing and Analysis

Raw accelerometer data were downloaded and converted to mean counts per 10-s using ActiLife software (v6.11.9) to determine wear-time compliance (days of valid wear time, average hours of wear per day). Qualtrics survey data were downloaded into comma separated value files and then uploaded into R (R Core Team, 2017). Once in R, each column was initially checked for errors. The lubridate package (Wickham, 2011) was used to convert the columns of participants' survey start and end dates and times into a usable date/time format. Mobile survey feasibility was determined by assessing the number of valid surveys completed, duration to complete the survey (start to finish), and total time to completion upon the survey receipt. Pearson's chi-squared tests were used to determine differences in survey completion based time block. Differences in proportions were considered statistically significant at the $p<0.05$ level. Finally, data were summarized regarding captured exercise bouts within the EMA window.

RESULTS

Survey Completion

Of the 1,624 surveys distributed, 1,348 (83%) were valid. 159 were not initiated, 18 were initiated but not completed, and 99 were completed, but outside the 60-min window. Valid surveys took 5±9-min to complete, and were generally taken within 17±15-min of SMS prompt receipt. The proportion of valid 9:30am surveys (78.8%) completed was significantly lower compared to those sent at 1:30pm (84.5%; X^2=4.02, p=0.022) and 9:30pm (86.7%; X^2=6.22, p= 0.006). The proportion of 5:30pm surveys (83.5%) was not statistically different from other proportions.

Reported Exercise Behavior

Eighteen participants reported 3-5 exercise bouts per week. Seven reported 0-2 bouts per week, and four reported 6-7 bouts per week. Of the 302 bouts reported, the most common mode was brisk walking (26.9%), followed by weight lifting (24.5%) and jogging/running (19.2%). The "other" category was the fourth highest reported classification (17.8%). In 23 instances, reports indicated sports/games or unlisted exercise modes. In 31 reports, write-in details indicated non-exercise behavior, such as chores (vacuuming, mowing the lawn, painting a room), transportation (walking between classes, taking "lots of stairs"), classroom activities (aerobic fitness test in a laboratory section), or work (bagging groceries).

Accelerometer Compliance

Most participants (83%) wore the accelerometer every day of enrollment (93% wore the accelerometer for at least 13 days). The average participant accumulated 12±2 days of valid (i.e. ≥10h) wear-time. On days where participants wore the accelerometer, the average wear time was 14.01±3.54 hrs per day (14.01±3.38 hrs in week one, 14.00±3.70 hrs in week 2). Two participants demonstrated relatively poor compliance, achieving only 5 or 6 days of valid wear-time.

Administrator Burden

Programming the survey distribution took approximately one hour per participant or cohort to pre-set the four surveys across 14 days. Based on recruitment rates, seven distributions contained 2-5 participants in the cohort and eight distributions were conducted for single individuals, necessitating 15 hours of effort. Data processing for one week of accelerometer data from one participant took 8-min, yielding an approximate total of 8 dedicated hours to this task.

DISCUSSION

Our results indicate that it is feasible to conduct a 14-day EMA of exercise behavior in college-aged adults using the combination of SMS and Internet capabilities of participant-owned smartphones. Further, the average amount of valid accelerometer wear-time accumulated by participants was acceptable, suggesting that accurate estimates of ambulatory behavior can be inferred. Concerns uncovered in our study should be addressed in future research aiming to understand the complexity of volitional exercise behavior.

Although our protocol elicited a sufficient response rate, student populations may present with unique barriers. We employed a similar survey distribution (i.e. four surveys per day across 14 days) to that of Dunton et. al (2009), and observed a higher response rate (83% vs. 76%) despite using a longer survey (27 items vs. ~17 items). This may be attributed to the use of different devices (participant-owned smartphone vs. researcher-provided PDA) and/or the sample population (college-aged adults vs. middle-age adults). However, our response rate was lower compared to a recent study (Ehlers 2016), where a 91% response rate was achieved in a sample of nine middle-age women. Comparatively, the researchers utilized a more concise survey (seven items) that was distributed based on individual participants' schedules to capture responses near waking and bed times, with a 2.5-h response window. This approach likely imposed less of a burden on participants and increased likelihood of taking the survey in their home environment with potentially fewer distractions. However, personalization of survey distribution did increase researcher burden (Ehlers et al., 2016). Despite young adults' ubiquitous use of and reliance on smartphones, several barriers emerged based on anecdotal data. First, several high-traffic buildings on campus consistently have poor cell service (e.g., the main library), which delayed the receipt of texts prompts. Second, the university where this study took place is one of over 100 North American universities that use Pocket Points[tm], a program that rewards students for locking their smartphones while on campus (Points, 2018).

Our study explicitly aimed to investigate exercise behavior, which departs from the general focus on physical activity throughout prior EMA literature (Bedard et al., 2017; Dunton, Dzubur, & Intille, 2016; Jones, Taylor, Liao, Intille, & Dunton, 2017). It is important to note that the use of accelerometry along with EMA is considered best practice (Kanning, Ebner-Priemer, & Schlicht, 2013). Accelerometry is a valuable asset for use along with EMA because it can reduce human error when reporting physical activity, sedentary time, and exercise.

However, with accelerometry only, exercise cannot be differentiated from physical activity. Thus, in addition to providing accelerometers, we specifically instructed participants to only report planned, structured exercise on each survey. However, at least 10% of cases where participants were to report exercise bouts, details were suggestive of non-exercise activity (e.g., painting, walking to class). This lack of compliance could inhibit the construction of adequate predictive models because the decision to exercise is likely influenced by different factors compared to those influencing decisions to do chores, job-related labor, or active transportation. Participants may have forgotten their instructions, necessitating that surveys contain a brief reminder on the definition of exercise. Alternately, it is possible that participants chose to perform household, work-related, or active transportation tasks in a labor-producing manner to burn extra calories, which may also be considered exercise behavior (Caspersen, Powell, & Christenson, 1985). In order to disentangle these concepts and add precision, researchers should incorporate additional items gauging non-exercise activity and intentions to provide evidence for classifying human movement as exercise.

The study is limited in terms of generalizability beyond non-Hispanic white university students assessed during summer and fall months. Compliance will likely be influenced by various demographic and seasonal factors. While Qualtrics provides a user-friendly survey distribution platform that is compatible with personal smartphones, the time burden and psychological energy devoted to attention to detail were relatively high. This is particularly a concern if participants are not recruited quickly enough to be organized into cohorts. While sending reminder prompts may have improved survey and accelerometer compliance, the already high burden prohibited additional distributions. Researchers should carefully weigh the options of sending more primary surveys vs. sending reminder prompts in a sample of participants.

In conclusion, it is feasible to collect sufficient data regarding EMA of university students' exercise behavior by capitalizing on commonly used smartphone features. In future studies, researchers should be cognizant of barriers to smartphone use in student populations and aim to disentangle reports exercise vs. non-exercise physical activity for added accuracy and precision.

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