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Using Ecological Momentary Assessment to Examine Antecedents and Correlates of Physical Activity Bouts in Adults Age 50+Years: A Pilot Study

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Abstract

Background—National recommendations supporting the promotion of multiple short (10+minute) physical activity bouts each day to increase overall physical activity levels in middle-aged and older adults underscore the need to identify antecedents and correlates of such daily physical activity episodes.

Purpose—This pilot study used Ecological Momentary Assessment to examine the time-lagged and concurrent effects of empirically supported social, cognitive, affective, and physiological factors on physical activity among adults age 50+years.

Methods—Participants (N=23) responded to diary prompts on a handheld computer four times per day across a 2-week period. Moderate-to-vigorous physical activity (MVPA), self-efficacy, positive and negative affect, control, demand, fatigue, energy, social interactions, and stressful events were assessed during each sequence.

Results—Multivariate results showed that greater selfefficacy and control predicted greater MVPA at each subsequent assessment throughout the day (p<0.05). Also, having a positive social interaction was concurrently related to higher levels of MVPA (p=0.052).

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Conclusion—Time-varying multidimensional individual processes predict within daily physical activity levels.

Keywords

Physical activity; Ecological momentary assessment; Psychosocial factors; Middle-aged and older adults

Introduction

Despite the known health benefits of physical activity for middle-aged and older adults [1, 2], participation in regular physical activity declines dramatically after adults reach age 50 [3]. Recommended levels of moderate-intensity physical activity (150+min/week) can be accumulated through relatively brief bouts, each lasting at least 10 min [4]. Promoting multiple short moderate-intensity episodes across the day is a promising approach to increasing physical activity in middle-aged and older adults who may have greater functional limitations and other health-related barriers to exercise relative to younger populations [5–7]. The importance of better understanding influences on daily physical activity levels is also supported by evidence of the daily acute effects (as opposed to longer term training effects) of physical activity behavior in certain health outcome areas (e.g., triglyceride concentration, insulin sensitivity, blood pressure, and immune function) [8–11]. However, we know little about how experiences or situations encountered throughout the day may hinder or enhance the likelihood of being physically active at that time point or at a subsequent moment of the day. Investigating the impact of time-varying circumstantial factors, as well as individual’s reactions to them, is an important step in developing effective lifestyle physical activity programs [12].

Both intraindividual (i.e., within-person) as well as interindividual (e.g., between-person) approaches are needed to understand how people make decisions to engage in physical activity across the day. The interindividual orientation has contributed to a large body of research examining dispositional characteristics, demographics, and other temporally invariant individual-level predictors of physical activity practices [13, 14]. However, there is some recent evidence to suggest that health-related cognitions and beliefs such as use attitudes, self-efficacy, and behavioral intentions can change over relatively short periods of time [15–17]. Research also suggests that acute within-person variations in positive and negative affect, anxiety, and anger are related to health behaviors such as caffeine consumption, smoking, and eating patterns across the day [18–22]. Further, studies show that fatigue ratings, which are negatively related to physical activity in middle-aged and older populations [23, 24], can change across the day [25]. To date, research has not examined systematically how within-person variability in state levels of cognitive, social, affective, contextual, and physiological factors impacts the likelihood of concurrent or subsequent physical activity across short periods of time (i.e., across a day).

This paper reports the results of a pilot study using Ecological Momentary Assessment (EMA) with electronic diaries to identify cognitive, social, affective, contextual, and physiological antecedents and correlates of physical activity episodes across the day among adults age 50+years. EMA is a novel measurement approach that allows the simultaneous assessment of psychological and behavioral variables as they naturally occur in real time. Electronic diary entries are time-stamped and, therefore, allow for valid comparisons of temporal relationships. Recent data suggest that electronic EMA is a feasible and a valid method of measuring physical activity among middle-aged and older adults [26] and adolescents [27]. We were primarily interested in developing and testing an initial model for understanding lagged and concurrent effects across the day. Issues concerning adherence and missing data were also explored.

Methods

Participants

The sample consisted of healthy, community-dwelling middle-aged to older adults from the San Francisco Bay area who did not engage in regular physical activity (as this pilot was aimed at better understanding factors that could inform subsequent intervention development for that population). The inclusion criteria were as follows: (a) 50 years or older, (b) able to read and speak English at the sixth grade level, (c) free of cardiovascular disease, (d) not participating in a regular program of physical activity (i.e., not exercising more than 60 min/week on a regular basis over the past 6 months), (e) willing and able to be instructed in using an electronic diary on a regular basis, and (f) residing in the local area. In total, 108 individuals were screened to determine eligibility. Seventy-seven percent (n=80) of the individuals screened were ineligible or did not wish to participate in the study. Being too active (55%), wanting information only (30%), and having a cardiovascular disease diagnosis (6%) were the main reasons for study ineligibility.

Procedure

Measurements were obtained using handheld electronic diaries (Cassiopeia E-125 Pocket PC, Casio, Inc. Dover, NJ). These devices are small (83.6[W]×131.2[L]×20.0[H] mm), portable, lightweight, and battery operated. Diary assessments began on the day after an initial orientation session. Using a fixed-interval measurement schedule, participants were assessed four times per day (7:45 a.m., 11:45 a.m., 3:45 p.m., and 7:45 p.m.) across a consecutive 2-week period. These assessment times were chosen to capture physical activity bouts occurring throughout the day (morning, midday, afternoon, evening), while minimizing recall errors associated with longer assessment windows. An auditory signal prompted participants to complete the diary sequence at each of the designated times. If they did not respond to the first prompt, a second auditory signal was emitted 10 min later. After each signal, participants had the choice of beginning the diary sequence or delaying it for 20 min. A 45-min window of time (e.g., 7:45–8:30 a.m.) was available to complete each assessment. After this time, the diary survey was not available until the next schedule assessment time. Further information about the electronic diary assessment procedures used in this study is available elsewhere [26].

Measures

Empirically supported cognitive, social, affective, contextual, and physiological factors and physical activity were measured through questions appearing in the electronic diary sequence. Questions were modified from past research using momentary assessments via pocket computers [28, 29]. The diary sequence contained several skip patterns based on responses to key questions. Approximately 2–4 min was required to finish each assessment.

Each diary sequence measured physical activity, selfefficacy, mood, several contextual variables (i.e., perceived situational control and demand), energy, fatigue, social interactions, and stressful events. Participants were asked whether and for how long (in minutes) they had performed each of 12 different types of activities including brisk walking, biking, dancing, heavy chores, jogging/running, hiking, aerobics, using fitness machines, and swimming. In order to calculate an indicator of moderate-to-vigorous physical activity (MVPA), we summed the minutes reported in each activity with a Metabolic Equivalent of 3.0 or more [30]. Adapted from previous measurement tools [31], selfefficacy for physical activity was assessed through the diary item: “How confident are you that you can engage in physical activity that increases your heart rate for at least 10 min during the next few hours?” A ten-point response scale was used ranging from “not at all confident” to “completely confident.” Mood was assessed by asking participants the extent to which they felt eight different types of emotions at the moment of the diary prompt. A ten-point response scale ranging from “none” to “extreme” was used for each item. A negative affect (NA) measure was created by averaging the scores for each of the following items (i.e., emotionally upset, stressed, lonely/alone, annoyed/angry, tense/anxious, sad/depressed, and discouraged/frustrated; Chronbach’s α=0.851). The positive affect (PA) measure consisted of one item (i.e., happy). Feeling fatigued/tired, energetic/full of pep, in control, and in demand at the moment of the diary assessment were also measured with the ten-point response scale ranging from “none” to “extreme.” Whether participants had a stressful/problematic or positive/uplifting social interaction in the past few hours was also assessed via the electronic diary. Lastly, participants were asked whether they had experienced a stressful event in the past few hours.

Data Analysis

Within-day effects were tested using multilevel random coefficient modeling (HLM version 6.0, Scientific Software International, Lincolnwood, IL) [32], a procedure for analyzing outcomes measured on repeated occasions within the same individual. Analyses examined the lagged effects of self-efficacy, PA, NA, fatigue, energy, control, and demand occurring during a specified time interval (T−1) on MVPA levels during the subsequent (lagged) time interval (T) within each day of monitoring. For example, it was determined whether self-efficacy, PA, NA, fatigue, energy, control, and demand reported at 7:45 a.m. predict subsequent physical activity reported at 11:45 a.m. on that same day. Due to the fact that social interactions and stressful events were assessed retrospectively (i.e., “have you experienced an event in the past few hours”), concurrent effects of these variables on MVPA (i.e., both the predictor and outcome were assessed during the same time interval) were examined.

Prior to data analyses, data were screened for violations of statistical assumptions. MVPA was positively skewed and thus subjected to a log transformation. In the first step of the analysis, a random intercept model with no predictor variables was tested to estimate between- and within-person variability. The second step tested multilevel models examining the bivariate relationships between each of the candidate predictor variables and $MVPA_T$. For each comparison, the level-one equation estimated the duration of $MVPA_T$ (in minutes; Y_{jk}) at each time interval as a function of the intercept (i.e., mean within-person level of $MVPA_T$; β_{0k}) and the predictor variable (i.e., self-efficacy, PA, NA, control, demand, fatigue, energy, having a positive social interaction, having a negative social interaction, or having a stressful event; β_{1k}). The level-two equations estimated the mean intercept ($MVPA_T$; γ_{00}) and coefficient for the association between the predictor variables and $MVPA_T$ (γ_{10}) across all people: $\beta_{00k}=\gamma_{00}+\mu_{0k}$ and $\beta_{01k}=\gamma_{10}+\mu_{1k}$. Predictor variables demonstrating a statistically significant bivariate relationship with $MVPA_T$ ($p<0.05$) were entered into the multivariate multilevel regression model in the third step. Due to the nonnormal distribution of the physical activity variables, robust standard errors were used.

Results

Sample

Participants included 23 adults, ages 50–76 years (M=60.65, SD=8.22 years). The average body mass index was 29.80 (SD=6.29). Seventy percent of the sample was female, 91% were non-Hispanic White, and 76% had a college degree of higher. Approximately 48% were employed full time, 48% were married, and 52% had an annual household income of $60,000 or more.

Missing Data

On average, participants missed or skipped approximately 13% (range=0–79%) of diary prompts during the entire monitoring period. Participants completed an average of 3.59 (SD=0.85) diary entries per day summing to a total of 983 diary entries (out of 1,288 diary prompts) across all participants. Missing data analyses showed that dairy prompts during the lagged interval (T) were more likely to be missed or skipped when self-efficacy ($p<0.001$), positive affect ($p=0.026$), and energy ($p=0.047$) were lower and when no positive social interaction occurred ($p=0.003$) at the previous diary prompt ($T-1$). The percentage of missing data did not vary with age, gender, race/ethnicity, marital status, employment status, or income. Missing data were imputed with person-level means for each variable, and this complete data set was used for all subsequent analyses. Linking between lead (time $T-1$) and lag (T) time intervals resulted in 965 time-matched diary entries. Not all diary entries could be time-matched due to the fact that the 7:45 a.m. T entry could not be linked to a preceding time interval (time $T-1$) within that same day.

Descriptive Statistics for Diary Data

Across all participants, the average time reported in $MVPA_T$ was 10.67 min (SD=19.41) for each 4-hour time interval between 7:45 a.m. and 7:45 p.m. Among participants reporting at least some $MVPA_T$ during a 4-hour time interval, the average duration was 22.55 min (SD=22.82). Approximately 11% of time-matched diary intervals reported a problematic social interaction, 42% reported a positive social interaction, and 10% reported a stressful event.

Between- and Within-Person Variability

The first step of the multilevel modeling involved testing a random intercept model with no predictor variables. The chi-square for the variance component was statistically significant, suggesting that there was significant between-person variation in physical activity (χ^2=489.44, *df*=22, *p*<0.001) (See Table 1). The intraclass correlation coefficient for physical activity was 0.337, which indicates that 33.7% of the total variance occurs between people, and 66.3% of the total variance lies within people [33]. Thus, there was considerable within-person variance available to explain by testing concurrent and time-lagged predictor variables.

Antecedents and Correlates of Physical Activity Bouts: Bivariate Analyses

The second step in the analysis involved entering the time-lagged and concurrent predictor variables separately in a bivariate fashion. Analyses were initially stratified by day of the week (weekend day versus weekday), but no differences were found (results not shown). Therefore, the remaining analyses combined data across days of the week. As shown in Table 2, greater self-efficacy$_{T-1}$, PA$_{T-1}$, and control$_{T-1}$ predicted higher levels of MVPA$_T$ during the subsequent diary interval (effect size *r*'s=0.51–0.70; *p*'s<0.05). There was also a positive association between energy$_{T-1}$ and MVPA$_T$, but the size of the effect was medium (*r*=0.30) and not detected as statistically significant (*p*=0.155) with the current sample. In contrast, greater NA$_{T-1}$ predicted lower levels of upcoming MVPA$_T$ (*p*=0.03). MVPA$_T$ levels were significantly higher during diary intervals when a positive social interaction$_T$ was reported as compared to when one was not reported (*p*<0.001). However, whether a problematic social interaction$_T$ or stressful event$_T$ was reported was not significantly related to levels of MVPA$_T$ during that diary interval (*p*'s>0.05). Fatigue$_{T-1}$ and demand$_{T-1}$ were also unrelated to MVPA$_T$ during the subsequent diary interval. The within-person variance in physical activity accounted for by each predictor variables was as follows: self-efficacy (10.2%), control (1.3%), demand (0.2%), energy (2.0%), fatigue (1.3%), NA (0.5%), PA (1.3%), experiencing a positive social interaction (2.8%), experiencing a negative social interaction (1.2%), and experiencing a stressful event (0.8%).

Antecedents and Correlates of Physical Activity Bouts: Multivariate Analyses

In the third step of the analysis, a multivariate multilevel random coefficient regression model examined the independent effects of each variable when all of the significant and marginal bivariate predictors (i.e., selfefficacy, PA, NA, control, energy, and having a positive social interaction) were entered simultaneously. Selfefficacy$_{T-1}$ (*p*<0.001), control$_{T-1}$ (*p*=0.009) and having a positive social interaction$_T$ (*p*=0.052) were independent predictors of MVPA$_T$ when all of the candidate variables were included in the model (data not shown). When MVPA was reported during a diary interval, approximately 35% of the co-occurring positive social interactions took place with a spouse or partner, 24% occurred with children, and 42% occurred with a friend.

Discussion

Results from this EMA pilot study expand our knowledge of the cognitive, social, affective, contextual, and physiological processes influencing participation in physical activity bouts across the day. Although physical activity has been found to improve mood [34], this is one of the first studies to suggest that variability in positive and negative affect can also have an impact on subsequent levels of physical activity throughout the day. Findings with regard to the relation of self-efficacy and perceived control to physical activity are consistent with past literature [35–38], yet suggest that these types of beliefs can exert influence over periods as short as a few hours (as opposed to periods spanning several days or more). The present study also increases our knowledge of how daily interpersonal processes contribute to variability of physical activity. Whereas previous studies generally show that social support is positively associated with physical activity [39], results from the present research provide insight into the role of social interactions, more specifically. Having a positive social interaction could motivate physical activity, or vice versa, because one feels a greater sense of competence or positive affect [40, 41]. Alternatively, social interactions during physical activity could be evaluated more positively if the behavior is perceived as fun and enjoyable (e.g., walking with friends, team sports). Although the directionality of this relationship cannot be determined with the current assessment protocol, the finding highlights the potential importance of the social encounter itself.

This project is one of the first studies to simultaneously assess time-matched antecedents and correlates of physical activity bouts through real-time data capture with electronic diaries. Attempts were made to bolster adherence to the diary prompting, such as limiting the number of items on each sequence and providing multiple reminder signals when an entry was missed. Consequently, the percentage of missing data was somewhat lower than other EMA studies [42, 43]. These missing data did not occur completely at random, however, as evidenced by the relation between the likelihood of missing a diary prompt and mood, energy, and other factors reported in the previous electronic diary entry. Future EMA studies should further develop strategies to maintain diary compliance within the context of circumstantial and situational challenges that are encountered throughout the day.

The results of the current study also help to uncover potential targets for future personal digital assistants or other portable communication platform-based interventions (e.g., mobile phones) to promote physical activity in middle-aged and older adults. With the introduction of increasingly sophisticated computing technology, electronically based methods offer new opportunities for health communication and promotion [44–46]. Hurling and colleagues [47] recently used Internet and mobile phone technology to increase physical activity in an adult sample. These Ecological Momentary Interventions seek to influence daily health behaviors by triggering self-regulatory and decision-making mechanisms in real-time [48]. With the advent of new technologies, self-report via electronic diaries can be coupled with objective real-time data capture techniques such as accelerometry, ambulatory assessments (e.g., heart rate, blood pressure, body temperature, blood glucose levels, respiration), and global positioning systems to provide a more complete picture of the interactions between physiological states, physical activity, and acute health effects.

Despite its methodological strengths, the current study had some limitations. Due to the small sample size and preliminary nature of this investigation, these results should be interpreted with caution. Future research should replicate these findings in a larger, more representative sample. This study was not adequately powered to detect small to medium effects. Post hoc power analysis showed 91% power to detect large effects ($r \geq 0.50$) and 44% power to detect medium effects ($r=0.30$). Second, the 4-hour data collection interval increases the potential for recall biases. Also, the fixed time-of-day sampling approach could cause reporting bias and measurement reactivity as participants learn to expect diary prompts at certain times of the day. Future EMA studies should assess these and other types of response biases such as social desirability, positive response bias, and boredom and burnout over time. Third, the number of items to assess psychosocial factors was restricted to reduce participant burden, precluding the ability to assess the reliability of several of the psychosocial variables. Fourth, the reliability and generalizability of the results may be limited by the small number of participants in the study ($N=23$) and the restricted demographic and geographical representation of the sample.

This research represents one of the first attempts to identify circumstantial antecedents and correlates of individual physical activity episodes occurring throughout the day among middle-aged and older adults. Findings suggest that many of the same constructs identified by between-person analyses also may influence physical activity participation on a within-daily basis. Whether the specific underlying mechanisms driving these relationships work within an acute as opposed to aggregated time frame remains to be explored. These results set the stage for additional research aimed at better understanding the factors that may have a daily influence on physical activity behavior, which can in turn have acute impacts on certain important aspects of health and functioning.

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Table 1

Between subject variance components from random intercept model predicting $MVPA_T$

Between subject variance component	Parameter	Variance estimate (μ)	Standard deviation	Chi-square	*df*	*p*
Intercept	τ_{00}	0.13	0.37	489.44	22	<0.001
	σ^2	0.26	0.51			

Data are based on 965 observations at level 1 and 23 participants at level 2. MVPA=Total minutes in moderate to vigorous physical activity in the past few hours (log transformed to correct for nonnormality)

Table 2

Summary of hierarchical linear modeling bivariate analyses for variables predicting $MVPA_T$

Within-subject fixed effects	Parameter	Coefficient	Robust SE	*t* ratio	*p*	*r*
Intercept	γ_{00}	0.45	0.08	5.87	<0.001	0.78
Self-efficacy $_{T-1}$	γ_{10}	0.07	0.01	4.57	<0.001	0.70
Control $_{T-1}$	γ_{10}	0.04	0.01	3.91	0.001	0.64
Demand $_{T-1}$	γ_{10}	−0.003	0.01	−0.27	0.789	0.06
PA $_{T-1}$	γ_{10}	0.05	0.02	2.76	0.012	0.51
NA $_{T-1}$	γ_{10}	−0.09	0.02	−4.90	<0.001	0.72
Energy $_{T-1}$	γ_{10}	0.03	0.02	1.47	0.155	0.30
Fatigue $_{T-1}$	γ_{10}	−0.01	0.01	−0.88	0.388	0.18
Positive Social Interaction $_T$	γ_{10}	0.15	0.05	2.85	0.010	0.52
Problematic Social Interaction $_T$	γ_{10}	0.02	0.08	0.21	0.834	0.04
Stressful event $_T$	γ_{10}	−0.03	0.07	−0.43	0.672	0.09

Data are based on 965 observations at level 1 and 23 participants at level 2. MVPA=Total minutes in moderate to vigorous physical activity in the past few hours (log transformed to correct for nonnormality). Subscript *T*−1=variable measured at the leading diary time interval. Subscript *T*= variable measured at lagged time interval. Robust standard errors are utilized *PA* positive affect, *NA* negative affect