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Feasibility and acceptability of intensive, real-time biobehavioral data collection using ecological momentary assessment, salivary biomarkers, and accelerometers among middle-aged African Americans

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Abstract

Perceived racial discrimination is linked to unhealthy behaviors and stress-related morbidities. A compelling body of research indicates that perceived racial discrimination may contribute to health disparities among African Americans (AAs). The purposes of this study were to describe the study protocol including data collection procedures and study measures and to evaluate the feasibility and acceptability of intensive biobehavioral data collection using ecological momentary assessment (EMA), salivary biomarkers, and accelerometers over 7 days among middle-aged AAs with a goal of understanding the relationships between perceived racial discrimination and biobehavioral responses to stress. Twelve AA men and women participated in the feasibility/acceptability study. They completed surveys, anthropometrics, and received in-person training in EMA and saliva sample collection at baseline. Participants were asked to respond to the random prompt text message-based EMA five times a day, wear an accelerometer daily for 7 days, and to self-collect saliva samples four times a day for 4 consecutive days. The EMA surveys included perceived racial discrimination, affective states, lifestyle behaviors, and social and physical

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CONFLICTS OF INTEREST

In the interest of full disclosure D. A. G. is founder and chief scientific and strategy advisor at Salimetrics LLC and Salivabio LLC and these relationships are managed by the policies of the committee's on conflict of interest at the Johns Hopkins University School of Medicine and the University of California at Irvine. The other authors have no conflicts of interests.

contexts. The mean EMA response rate was 82.8%. All participants collected saliva samples four times a day for 4 consecutive days. About 83% of participants wore the accelerometer on the hip 6 out of 7 days. Despite the perception that the intensive nature of assessments would result in high participant burden, the acceptability of the study procedures was uniformly favorable.

Keywords

African American; ecological momentary assessment; feasibility; racial discrimination; salivary biomarkers; stress

1 | INTRODUCTION

African Americans (AAs) experience disproportionate burdens of higher rates of cardiovascular disease and metabolic disorders than their White counterparts (Blackwell, Lucas, & Clarke, 2014). They also have higher rates of engaging in unhealthy lifestyle behaviors that may lead to health problems (Blackwell et al., 2014; Tussing-Humphreys, Fitzgibbon, Kong, & Odoms-Young, 2013). A compelling body of research indicates that exposure to stressful events is associated with unhealthy lifestyle behaviors and contributes to poor health and health disparities (Brondolo, Gallo, & Myers, 2009; Ford et al., 2016; Lewis et al., 2006). The stressful events that AAs commonly experience are multifactorial, often compounded by racial and sexual issues and by other socioeconomic strains (Dickerson, Gable, Irwin, Aziz, & Kemeny, 2009).

Racial discrimination is a social evaluative threat that can elicit biological disruption by dysregulation of the sympathetic–adrenal–medullary (SAM) system and the hypothalamic–pituitary–adrenal axis that play important roles in the stress response system (Dickerson et al., 2009; Kemeny, 2003). Studies have also shown that behavioral responses to the social stressors may differ and contribute to unhealthy lifestyles, such as drinking, overeating, and smoking rather than engaging in physical activity or healthy eating because the social stressors influence cognitive stress appraisal (threat vs. challenge) and subsequent affective states (Diehl, Hay, & Chui, 2012; Folkman, 1988). To date, however, few studies have prospectively evaluated the impact of perceived racial discrimination—a unique and salient social stressor affecting health—with a multisystem approach inclusive of behavioral responses and affective states (e.g., mood) among AAs.

Ecological momentary assessment (EMA) is a real-time data capture strategy that collects information prospectively in real-world settings where people engage in their typical routines in their everyday lives (Heron, Everhart, McHale, & Smyth, 2017; Shiffman, Stone, & Hufford, 2008). The ecological validity, where the study findings can be generalized to real-life settings, may be enhanced by EMA by allowing researchers to study process and self-report data that vary across place and time in participant's everyday contexts. Instead of averaging recall measures (e.g., past months) of perceived stress, mood and behaviors—which often do not take into account dynamic patterns of change over time—EMA provides a more ecologically valid picture of real-world processes with multiple brief assessments collected over a relatively short time period (Heron et al., 2017; Shiffman et al., 2008).

To date, most studies on racial discrimination and health have focused on major stressful or discrimination events that were collected retrospectively, where respondents needed to cognitively aggregate and summarize their experiences in the recent past. Such data are subject to recall and rumination bias. In some cases, for example, a form of racial discrimination—racial microaggressions defined as commonplace daily race-based biases and prejudices, including verbal or nonverbal denigrating messages—may have been too subtle to be captured with a retrospective survey but may have influenced subsequent mood and health behaviors and are, thus, important to be examined (Nadal, Griffin, Wong, Hamit, & Rasmus, 2014; Sue et al., 2008). Racial microaggressions have been understudied in AAs. We will incorporate microaggressions in studying perceived racial discrimination using EMA.

Although increased physical activity may buffer the impact of stress related to racial discrimination, data on the relationship between racial discrimination and physical activity in AAs are sparse. In the Jackson Heart Study cohort, perceived racial discrimination was linked to unhealthy behaviors such as the consumption of fatty foods and smoking (Sims et al., 2016). An unexpected finding in the study, however, was that higher everyday and lifetime discrimination was associated with more physical activity in women based on their self-reported physical activity (Sims et al., 2016). In another study of physical activity measured by pedometers, racial discrimination was not associated with physical activity when examined among the full sample or separately by race/ethnicity (Shelton et al., 2009). Studies with objective measures such as accelerometers that can minimize the weakness of self-report measures of physical activity are needed to elucidate the relationship of racial discrimination and physical activity. Limited data are available, however, to ascertain whether the use of such multiple real-time subjective and objective measures is feasible and acceptable in AAs. There is a need for evidence to support the feasibility and acceptability for future research.

There is growing interest in the ability to detect stress-immune-inflammatory markers in response to psychological stress within naturally occurring social contexts at multiple time points per day to capture the diurnal patterns of stress biomarkers across the day. Salivary biomarker collection is a less invasive process than venipuncture blood marker collection and enables intensive data collection, involving extensive repeated measures per day over time in a naturalistic environment such as a participant’s home. The use of EMA, combined with salivary biomarkers that can capture real-time psychological stress, racial discrimination experience, and subsequent affective states, health behaviors and biological responses, may enhance our understating of the effect of racial discrimination on health (e.g., immune function) and health behaviors. Yet, the feasibility and acceptability of such intensive data collection in AAs who suffer from stress-related health disparities are still unknown.

Obtaining information on perceived racial discrimination, affective states, and behavioral patterns by EMA—paired with the use of minimally invasive, salivary biomarkers, and accelerometers—is crucial to develop future just-in-time interventions, where the personalized intervention content is sent to participants at just the right time to improve

health outcomes for AAs. Thus, examining the feasibility and acceptability of using such measures is a necessary step for the future studies in AAs.

The purpose of the study was to evaluate the feasibility and acceptability of intensive biobehavioral data collection using random prompt text message-based EMA, salivary biomarkers, and accelerometers for physical activity measurement over 7 days among 12 young and middle-aged AA men and women.

2 | METHODS

2.1 | Design

This is a pilot prospective study to evaluate the feasibility and acceptability of intensive biobehavioral data collection using EMA, salivary biomarkers, and accelerometers in AAs.

2.2 | Study settings and participants

Participants were recruited from the Greater New Haven communities in Connecticut. The research team has collaborated with the Yale Cultural Ambassador groups, representatives of New Haven's AA church communities who partner with researchers in community-engaged research. We presented the purpose and procedures of the study at meetings with the church leadership groups, and recruited participants through referrals from the leadership groups. When potential participants contacted us, we screened them by phone, answered their questions, and scheduled a baseline orientation visit.

The following issues were considered in establishing the inclusion and exclusion criteria. Technology use (i.e., EMA), lifestyle and the association between racial discrimination and the physiological responses to stress (e.g., cortisol output) may differ by sex and age (e.g., menopausal transition; Boutwell et al., 2017; Korous, Causadias, & Casper, 2017; Pew Research Center, 2018; Saint Onge & Krueger, 2017). We focused on young- and middle-aged, currently working groups, who were more likely to be exposed to and to experience daily stress and competing demands from multiple sources from parenting and work.

Inclusion criteria were (a) self-reported AA/Black, (b) age 30–55, (c) currently employed, (d) ownership of a smartphone, (e) able to respond to EMA prompts at least 3×/day, and (f) English speaking. We excluded those who were (a) pregnant, (b) participating in another study that may have increased the subject's burden of participating in the current study or influence our study outcomes, (c) had serious acute or terminal medical conditions, (d) had other medical conditions that confound salivary biomarker outcomes (e.g., radiation of salivary glands, Cushing's or Addison's disease; Bhattarai, Junjappa, Handigund, Kim, & Chae, 2018), (e) had active thought disorders, (f) were using current psychotropic, corticosteroid or cytokine-based treatment (Bhattarai, Kim, & Chae, 2018), or (g) shift-workers because variations in circadian rhythms of shift-workers affect cortisol (Kudielka, Buchtal, Uhde, & Wust, 2007).

Sample size ($n = 12$) was largely based on guidelines for pilot studies that suggest 10–40 participants per cell (Hertzog, 2008). Even assuming moderate attrition (20%), we would

have 10 subjects, which is still within the guidelines for pilot studies (Rounsaville, 2001). We also determined the effect sizes based on cross-sectional correlations of predictors and intraclass correlations (ICCs) of outcomes measured on repeated occasions within the same individual. Based on a previous study (Stawski, Cichy, Piazza, & Almeida, 2013), we anticipated an ICC of 0.34–0.47 and design effects of 3.06–3.83 on the various cortisol indices measured for 7 days. By adjusting for the design effects, the expected 84 (=7 days × 12 people) observations from 12 participants up to 552 (4×/day × 4 days of saliva collection ×12 people) observations would be able to detect medium effect sizes of 0.53–0.60 with 80% power at a 5% significance level.

2.3 | Procedures

We obtained Institutional Review Board approval and written informed consent from all participants. Before the first visit, we asked participants for their sleep/wake/commuting schedules to accommodate EMA delivery time by phone.

2.3.1 | Baseline visit—We asked participants to attend a 90-min baseline study visit at their convenient location, such as their home, work, or church. The baseline visit consisted of paper-pencil surveys, measurements of body weight, height, percent body fat, and blood pressure, and a collection of a hair sample for hair cortisol measurement (data not shown in this study). The survey included sociodemographics, current medication use, and smoking status. We also used the validated measures such as the Charlson Comorbidity Index for comorbidities (α = .85; Charlson, Szatrowski, Peterson, & Gold, 1994) and the Alcohol Use Disorders Identification Test for alcohol consumptions (α = .85; Daeppen, Yersin, Landry, Pecoud, & Decrey, 2000). A trained research assistant measured body weight and height using a portable electronic scale (Omron HBF-514C Full-Body Sensor Body Composition Monitor and Scale) and a stadiometer (Seca) following standard procedures. Heavy clothes, shoes, and socks were removed before weighting and measuring in a private setting. Height was measured to the nearest 0.1 cm using a stadiometer and weight was measured to the nearest 0.1 kg with a high-precision electronic digital scale. Body mass index (BMI) was calculated as weight (kg)/height squared (m^2). Percent body fat was measured using the same digital scale that measures foot-to-foot bioelectric impedance. This method has demonstrated significant correlations with gold standards of body fat calculation (i.e., dual-energy X-ray absorptiometry [DEXA]; Deurenberg, van der Kooy, Leenen, Weststrate, & Seidell, 1991; Jaffrin & Morel, 2008). After 5 minutes rest, blood pressure was measured twice by an automated cuff (Omron HEM 780 IntelliSense Automatic Blood Pressure Monitor), with 1 min between readings; the average of the two readings was recorded. We included both saliva and hair measures of cortisol to provide complementary information because hair cortisol is a stable and feasible measure as a chronic, cumulative stress marker, whereas salivary cortisol reflects acute and transient reactivity as part of adaptive stress responses (Sapolsky, Romero, & Munck, 2000; Stalder & Kirschbaum, 2012). At the baseline visit, trained research staff cut a small amount of hair (30 μg) with scissors from the posterior vertex region of the participant's head and trimmed to 3 cm in length, which reflects cortisol secretion over the past 12 weeks (Gidlow, Randall, Gillman, Silk, & Jones, 2016). We asked participants to wear an accelerometer for 7 days to measure their physical activity levels. All participants received one-on-one training in EMA surveys,

and saliva at-home-collection and storage with a study folder. This included pictures and step-by-step written instructions of usage of EMA, saliva collections and accelerometers, a tiered payment schedule, and research staff contact information. We sent reminders through EMA to wear an accelerometer daily for 7 days and collecting saliva four times a day for the first 4 days.

2.3.2 | EMA protocol—At the baseline visit, we loaded the mEMA app (https://ilumivu.com)—which is compatible with both iOS and Android operating systems—into participants' smartphones.

Each EMA survey prompted each participant at a random time within five pre-programmed windows to ensure adequate spacing across the day except for nighttime. EMA surveys were prompted using an auditory signal or vibration. Participants were asked to carry their smartphone for 7 consecutive days to respond to EMA prompts. The EMA data collection system recorded the date and time it took each participant to respond to a random prompt survey, and the date and time a survey expired. The survey expired after 40 min of nonresponse. After no entry was made, the EMA program became inaccessible until the next recording opportunity. Each EMA survey took ~3–4 min to answer. Table 1 presents an example schedule for EMA delivery.

2.3.3 | Saliva self-collection protocol—Participants received a detailed instruction and 16 numbered, color-coded cryovial collection devices. They were asked to self-collect 1.5 ml of unstimulated whole saliva via passive drool (Granger, Johnson, Szanton, Out, & Schumann, 2012) using a saliva collection aid (Salivabio, Carlsbad, CA) four times a day (at wakeup, 30 min later, just before dinner, and at bedtime) for 4 consecutive days and to store the samples in their home freezer until the samples were picked up by research staff. Participants were prompted by the smartphone-based EMA to collect a sample and asked to write saliva collection times and dates in collection kits and send a picture through EMA (Figure 1). At the end of the 7-day period, research staff transported the saliva samples from the participants' homes with a cooler with ice packs. Then, the samples were frozen in −80°C in the freezer at the Yale School of Nursing biobehavioral lab. The frozen samples were transported overnight to the Institute for Interdisciplinary Salivary Bioscience Research, where they were assayed in batch.

2.3.4 | Accelerometer protocol—Participants were asked to wear a triaxial hip accelerometer (ActiGraph GT9X) on their right hip during waking hours for 7 consecutive days to obtain at least 3 weekdays and 1 weekend day to determine the daily variability (Hagstromer, Oja, & Sjostrom, 2007; Troiano et al., 2008). A paper diary was provided and participants were instructed to fill out the diary on the time they took off and wore their accelerometers. At the end of their wear period, we collected their accelerometers in person and the data were downloaded using ActiLife software (ActiGraph, Pensacola, FL).

2.3.5 | Participant payments—Participants who completed the baseline visit—which included paper-pencil surveys, hair sample collection, anthropometric data collection and training in study protocols—received $30. In addition, we had a tiered payment schedule

(<50%; 50–79%; >80%, up to $200) depending on the participants' EMA survey responses, adherence to saliva sample collections and wearing their accelerometer.

2.4 | Measures and variables

Table 2 summarized study measures, variables, and data collection methods.

2.4.1 | EMA measures—*Racial discrimination/microaggressions* were measured by the experiences of discrimination (EOD; $\alpha > .88$; Krieger, Smith, Naishadham, Hartman, & Barbeau, 2005) and the Racial Microaggression Scale (RMAS; $\alpha > .85$; Torres-Harding, Andrade, & Romero Diaz, 2012; Williams, Yan, Jackson, & Anderson, 1997) adapted for EMA data collection. The EOD has subscales for worry, global, filed complaints, response to unfair treatment, day-to-day discrimination, and skin color; for example: "Over the past few hours, have you experienced any of the following things because of your race/ethnicity?" (Yes/No). Respondents indicated whether they have ever experienced each event (*yes* = 1/*no* = 0), and all items were summed for a total EOD score. The RMAS with a 7-point scale (1 = *strongly disagree* to 7 = *strongly agree*) has subscales for invisibility, criminality, low-achieving/undesirable culture, sexualization, foreigner/not belonging, and environmental invalidations. The total summary score was calculated by adding all of the values and dividing by the number of items.

Affective states were measured by asking participants the extent to which they felt eight different types of emotions at the moment of the prompt. A 10-point response scale ranging from *"not at all"* to *"extreme"* (e.g., "How tense or anxious do you feel right now?") was used for each item. A negative affect measure was created by averaging the scores for each of the following items: emotionally upset, stressed, lonely/alone, annoyed/angry, tense/anxious, sad/depressed, and discouraged/frustrated ($\alpha = .85$ in this study). The positive affect measure was one item—happy.

Lifestyle behaviors were measured by asking the following questions based on the EMA measures of lifestyle behaviors (Dunton et al., 2015; Dunton, Liao, Kawabata, & Intille, 2012); for example, "Right before the phone went off, were you engaged in any of following activities?" [check all that apply]—for example, smoked, physical activity, eaten something, had drinks, and so forth. A follow-up branching sequence was also initiated; for example, the type and duration of physical activity, and the type and amount of food intake.

Social and physical contexts were measured by the following questions "Where were you over the past few hours?" and "Who were you with over the past few hours?" Each question has a range of options and an "other" response option with a text box for options not listed. Figure 2 presents examples of EMA surveys.

2.4.2 | Salivary biomarker determinations—On the day of assay, the samples were thawed, centrifuged (to remove mucins) and assayed in duplicate for the following: cortisol (adrenocortical stress response via hypothalamic–pituitary–adrenal axis); salivary alpha-amylase (sAA: Autonomic nervous system stress response via SAM pathway axis); secretory immunoglobulin A (S-IgA), C-reactive protein (CRP), and interleukin-6 (IL-6) (immune/inflammatory markers) using commercially available assays specifically designed

for use with saliva (Salimetrics, Carlsbad, CA) without modification to the manufacturer's recommended protocols. For all assays, the inter- and intra-assay coefficients of variation were, on average, less than 15% and 10%, respectively. Collection of saliva four times per day permitted assessment of the within-day effect of key components of sAA and the diurnal cortisol rhythm (i.e., a total cortisol output, cortisol awakening response, the diurnal cortisol slope). All other salivary markers (S-IgA, CRP, and IL-6) were assayed from the first AM sample only (Deinzer & Schuller, 1998; Hucklebridge, Clow, & Evans, 1998; Tsujita & Morimoto, 1999).

2.4.3 | Physical activity—The objective physical activity was measured with a triaxial hip accelerometer (ActiGraph GT9X). Sensors were initialized to sample movement at 30 Hz and raw data were aggregated into 60-s epochs for waking hours (Chen, Janz, Zhu, & Brychta, 2012; Heil, Brage, & Rothney, 2012). Data were screened to include valid days (≥10hr-valid wear-time) and summarized at the day level. Physical activity was operationalized as daily minutes using validated thresholds accelerometry (sedentary < 100 counts/min; moderate 2,020; vigorous 5,999; Troiano et al., 2008). The accelerometer recordings were time-stamped to be linked with the EMA and salivary data. After filtering out sleep windows, the non-wear periods were defined as ≥60 consecutive minutes of zero activity intensity counts, with allowance for 1–2 min of counts between 0 and 100 and we considered a day valid if ≥10 hr of activity counts were collected (Troiano et al., 2008). Triaxial hip accelerometry physical activity assessment has demonstrated excellent test-retest reliability (ICC = 0.70–0.90; Sirard, Forsyth, Oakes, & Schmitz, 2011), as well as moderate criterion validity (r = .59; Pedisic & Bauman, 2015).

2.4.4 | Feasibility—Feasibility was defined by a retention rate (>80%) and response/adherence rates (>70%) for the three measures: EMA responses, saliva collections, and accelerometers. Retention was defined as the percentage of participants who completed the EMA survey at least 3×/day and on 5 of the possible 7 days of EMA data collection. The EMA survey response rate was measured by the proportion of completed surveys (i.e., all 8–15 questions were answered) out of all 35 surveys sent to the participant's phone. The number of EMA responses per day was also measured. The adherence to saliva collections was defined as the percentage of the collected saliva sample out of a total of 16 collections (4x×/day for 4 days). The adherence to wearing an accelerometer was defined as days with valid wear-time (≥ 10 hr/day) out of 7 days.

2.4.5 | Acceptability—To understand participants' experiences on the intensive data collection procedures, we interviewed each participant in-person after the 7 days of study participation, using five brief questions, three close-ended and two open-ended. We asked about the following: (a) overall satisfaction with the study protocols, (b) challenges in saliva collection and storage (reverse scoring), and (c) willingness to participate in a similar future study using a 5-point Likert scale, with greater values indicating more satisfaction. We also asked their experiences in EMA and the EMA frequency using open-ended questions.

2.5 | Adherence monitoring and communications

The mEMA provided survey response monitoring (i.e., adherence) in real-time through a web-based interface. For the first 2 days, research staff checked participants' mEMA dashboard through the web-based interface twice a day to see whether EMA surveys were sent as scheduled and whether participants responded to surveys. We contacted all participants via text messages: (a) to provide positive feedback to reinforce and reassure the participants on their good adherence to the EMA protocols; (b) and to ascertain whether the participants had any difficulty receiving the EMA surveys or responding to the surveys.

For saliva collection, if participants did not send us pictures of their collected saliva tubes through EMA, we sent them a text message to determine whether they were still collecting their saliva samples without sending the pictures and asked whether they had any questions regarding saliva collection. Although participants were allowed to send us text messages any time during the study period, we contacted all participants via text messages on Day 4 again to check whether they had any problems following the study protocols, and to remind them to store the completed saliva samples in their home freezer until we collected the samples on Day 7. Upon completion of the study, we shared the summary report of the adherence generated by mEMA portal and ActiGraph software with each participant and paid them. Text messages were the most frequently used communication tools between our research participants and research team. Our research team responded to participants' texts within 1–2 hr from their initial messages.

2.6 | Data analysis

EMA data were exported from the mEMA server to comma-separated values format. Accelerometer data were scored with ActiLife software (ActiGraph, Pensacola, FL) to create the following variables: total wear-time (min), daily wear-time (hr/day), moderate–vigorous physical activity (min/day), and sedentary time (hr/day). We entered the EMA, saliva and accelerometer data, as well as the baseline surveys and clinical data into a database uploaded into SPSS for analysis. We reviewed the data and corrected errors, evaluated missing data, outliers, and skewness, and calculated the scale scores for the EMA responses. To describe our sample characteristics, we used means and standard deviations (*SD*) for the continuous variables, and frequencies and percentages for the categorical variables. We conducted a content analysis for the two open-ended questions on experiences in EMA use and the EMA frequency. Open coding was formulated into meaningful subcategories independently by two researchers. Then, the subcategories were reviewed and grouped under higher order headings to generate main categories.

3 | RESULTS

Participant characteristics and descriptive statistics of the selected variables from physiological and accelerometer data are presented in Table 3. The mean age was 43.42 years. Over 80% were college graduates. About 66% had annual income <$60,000. The mean BMI was 34.19 kg/cm^2 (*SD*, 11.41); about 42% of the participants were obese. The mean moderate-to-vigorous physical activity was 18.5 min/day and the mean sedentary time was 8.6 hr/day.

3.1 | Feasibility

The retention rate of the study was 91.6%. In terms of setting up for the EMA delivery time window, we found that each participant's daily routine schedule was quite different. Some participants who were not shift-workers worked from afternoon to midnight and woke up around lunchtime. We individualized and sent the EMA survey based on participants' sleep/wake/commuting time. Table 4 shows the mean response and adherence rates of each data collection protocol. The mean response rate for EMA surveys was 82.8% (*SD*, 16.3). Women (87.5%) had a greater response rate than men (70.3%). The mean number of EMA responses per day was 3.96 (*SD*, 1.21) out of a possible maximum of 5 per day.

All participants collected saliva samples, 4×/day for 4 consecutive days as instructed (100% adherence). Each donated saliva sample had sufficient sample volume for the assays to be performed for each analyte in duplicate. All participants wrote the time and dates for their saliva collection times on collection kits (100% adherence). Six out of 12 participants (50%) also sent real-time pictures of all 16 saliva collections through EMA. All samples returned assay values within range—mean values (*SD*s in parentheses) were 0.27 μg/dl (0.26) for cortisol; 41.5 pg/ml (65.0) for IL-6; 1,877.8 μg/ml (1,712.36) for S-IgA; 2,937.0 pg/ml (5,599.7) for CRP; and 148.0 U/ml (114.3) for sAA. Ten out of 12 participants (83.3%) wore the accelerometer on the hip 6 out of 7 days. Nine out of 12 participants (75%) recorded the time they wore and took off their accelerometers. Ten out of 12 participants (83.3%) met the inclusion requirement for valid accelerometer data (≥10 hr/day wear-time). In the bivariate analyses, the higher EMA response rates were significantly associated with part-time employment status ($r = -.65$; $p = .02$) and older age ($r = -.62$; $p = .03$).

3.2 | Acceptability

Participants reported that the acceptability of the overall study procedures was uniformly favorable (mean ± *SD*, 4.58 ± 0.66). Many participants reported that collecting and storing saliva four times a day for 4 days were not challenging (mean ± *SD*, 4.33 ± 0.65). All participants expressed willingness to participate in a similar future study (mean ± *SD*, 4.41 ± 1.08). None of the participants reported that responding to EMA was boring or stressful. Nine out of 12 participants (75%) showed positive responses on EMA surveys describing as "fun," "helpful," and "enjoyable." Ten out of 12 participants (83.3%) reported that the frequency of the EMA survey (5x/day) was appropriate. Two participants reported that 3–4×/day of EMA should be good to assess racial discrimination experience, mood, and accompanying health behaviors.

3.3 | Occurrence of errors or incidents

Three participants (25%) reported that they received error messages from the EMA app showing "the survey is not sent" or "upload failure." The total number of error messages was six; these happened during the first 2 days of the data collection period. These malfunctions were found to be attributed to insufficient memory/storage on the participant's phone or no/weak Internet connection issues. After we communicated with the participants regarding the potential problems and strategies (e.g., deleting or moving videos/photos to clouds to make available storage, deleting unnecessary mobile apps), we did not receive further problem reports from participants. All participants expressed appreciation of our timely feedback and

assistance. For accelerometers, one participant lost her accelerometer on Day 5 after she had been wearing it for the past 4 days and found it the next day, in the Lost and Found of a local shop.

4 | DISCUSSION

We demonstrated the feasibility and acceptability of an intensive data collection from middle-aged AA men and women who successfully provided real-time self-report data using smartphone-based EMA, collected saliva samples to measure biomarkers of stress response, and also wore accelerometers as objective measures of physical activity. We had high retention and response/adherence rates for all data collection protocols.

The mean EMA response rate in our sample was similar to other studies or relatively high considering the other concurrent study activities such as saliva collection, and wearing accelerometers (Dunton, Liao, Intille, Spruijt-Metz, & Pentz, 2011; Liao, Skelton, Dunton, & Bruening, 2016). Consistent with other studies that included ethnic minority men and women, women showed higher EMA response rates than men (Cook, McElwain, & Bradley-Springer, 2010; Liu & Lou, 2018). Given the small number of men in our study participants, we can only speculate that woman may be more expressive and tend to report their momentary status and may be more engaging with an app-based survey than men. Participants with an older age and who worked part-time had higher response rates than their counterparts. Future efforts should include strategies to improve the feasibility and consider appropriate approaches in real-time data collection among the subgroups of populations who may have challenges and limitations to participate in a study using EMA.

We were successful in participant-administered saliva sample collections. All of our participants collected their saliva samples four times a day for 4 consecutive days as instructed. Participants also reported in the satisfaction survey that collecting saliva four times a day for 4 days and storing was not challenging. We trained participants and provided detailed written instructions with pictures at baseline visits. Using the 16 numbered (4×/day for 4 consecutive days), color-coded cryovials for passive drool methods were also helpful to avoid errors in collecting saliva in the designated cryovials. Ten out of 12 participants met the inclusion requirement for valid accelerometer data (83.3%). Based on the adherence rates and the findings from satisfaction surveys, wearing an accelerometer for 7 days seemed to be feasible among middle-aged AAs.

4.1 | Challenges and lessons learned

There were also challenges in conducting the study. Given the nature of the pilot study with such intensive real-time data collection, we made substantial time and effort in making plans and communicating with participants, from scheduling the baseline visits to the end of study period to ensure that the study protocol was not only clear to the participants but also convenient for them.

We learned that it is necessary to accommodate each participant’s lifestyle routine and individualize the EMA delivery schedule according to waking and sleep patterns, and work schedule to enhance participants’ adherence to the study protocol. It is also important to

understand the context of individual's lifestyle behaviors, particularly when real-time data collection is involved, or circadian rhythms (e.g., cortisol) play an important role in study variables.

The lessons we learned from the current study are the importance of early and timely assistance, flexibility, and effective communication with participants. From the first day of data collection, we started EMA data monitoring by the mEMA dashboard and provided positive feedback to reinforce participants' good adherence to the study protocols and addressed the technical issues and assisted them accordingly. Most of our participants did not need assistance after the first 1 to 2 days.

It was also important to provide flexible time and place for study visits for participants, including evening hours, early morning before going to work, and weekends, to accommodate participants' schedules. Many participants preferred to meet us during lunchtime or at the end of the day at their workplace instead of at home. The 90-min baseline visit provided sufficient time for training of EMA and saliva collection and baseline data collection for our middle-aged AA participants who had been using a smartphone before the study.

With the pilot study, we were able to determine how much training the potential participants needed for EMA and saliva sample collection and the appropriate frequency and delivery time of EMA data collection. Also, we learned how we effectively communicate with participants during the study, how we monitor their adherence to study protocol, and what resources are needed in terms of space for data collection and the use of software for data collection and analysis.

We believe that a tiered payment schedule based on the adherence to the study protocols may have enhanced the levels of participation. We used objective adherence data generated by mEMA platform and ActiLife software, showing the time of EMA surveys sent, the number of EMA responses, and the total wear-time of accelerometer.

4.2 | Implications and contributions to future research and clinical practice

The real-time data collection in the natural environment that we conducted in the current study may provide some implications for clinical practice and future research on psychological stress and biobehavioral responses. Providing personalized, patient-centered care has been shown to be associated with better health outcomes (Bertsimas, Kallus, Weinstein, & Zhuo, 2017), but it often requires real-time lifestyle behavior tracking and timely interventions. Using EMA, a real-time, self-report data collection strategy would reduce the recall bias where healthcare providers often have to rely on information collected retrospectively at patients' sporadic office visits. It also increases the ecological validity of research because data are collected in participants' daily natural environment rather than in labs or other controlled research settings. Furthermore, the feasibility of collecting data using EMA, combined with objective physiologic measures that we demonstrated in this study may provide insight into the development of personalized ecological momentary interventions delivered by mobile phones, where personalized intervention content is sent to the right person at just the right time (i.e., the point-of-need) and in the right context

(Heron & Smyth, 2010). Use of mHealth technology (e.g., EMA) is ubiquitous; smartphone ownership and use are 75–77% among Whites, Blacks, and Hispanics; 67% among those whose annual income is less than $30,000% and 93% among those whose annual income is over $75,000 (Pew Research Center, 2018). Therefore, ecological momentary interventions have great potential to reduce health disparities by reaching out to underserved, hard-to-reach populations and by providing personalized interventions such as stress management and coping behaviors at the needed time.

In summary, our study addressed weaknesses of the current methodology of assessment that may be subject to recall bias by collecting participant's self-report data on stress, mood, and behavior and the context of the behavior in real-time, at multiple time points in their natural environment. The feasibility and acceptability of using intensive repeated assessments that we showed in our pilot study and the potential utility of EMA—paired with using objective measures of salivary stress markers and accelerometers—will guide and improve models of the psychological, behavioral, and physiological processes by which repeated stress affects AAs health and health behaviors.

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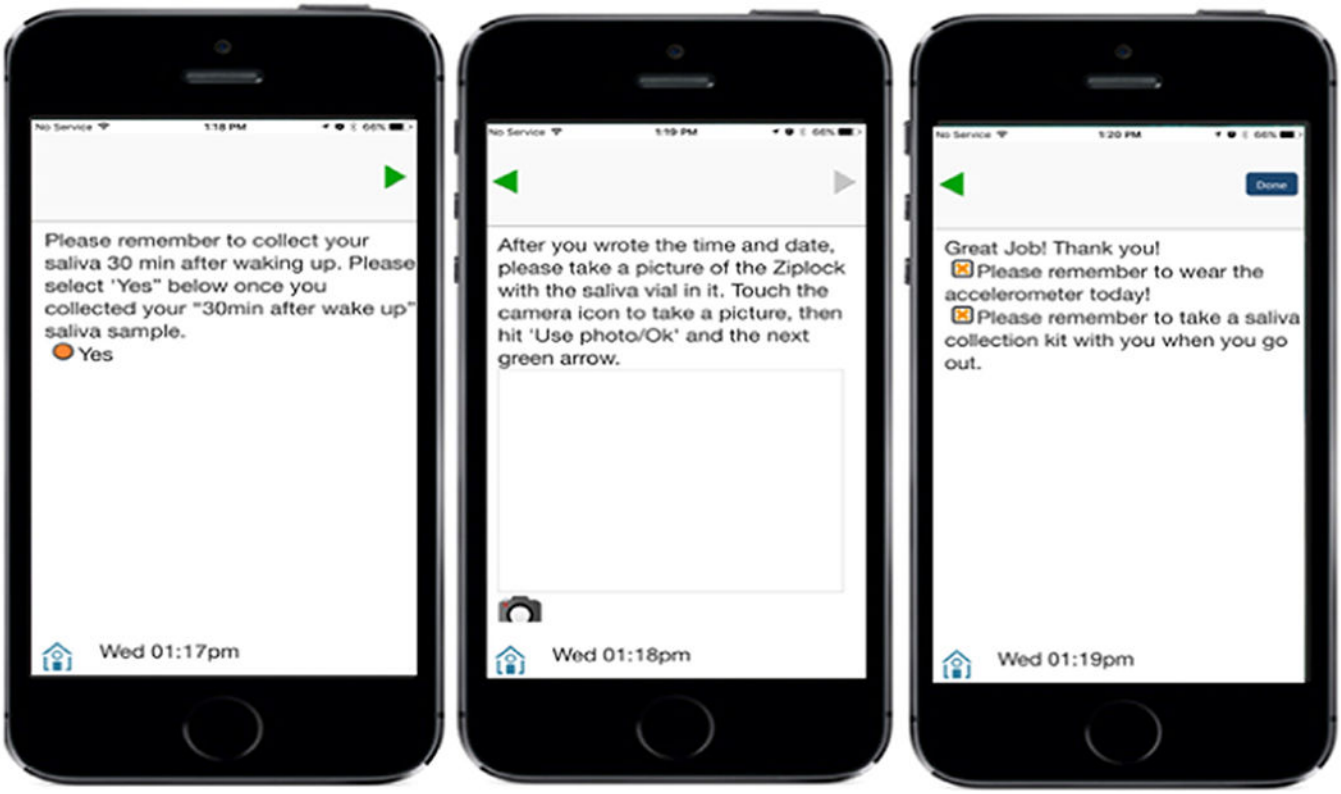

FIGURE 1.
Pictures of saliva sample collection reminders [Color figure can be viewed at wileyonlinelibrary.com]

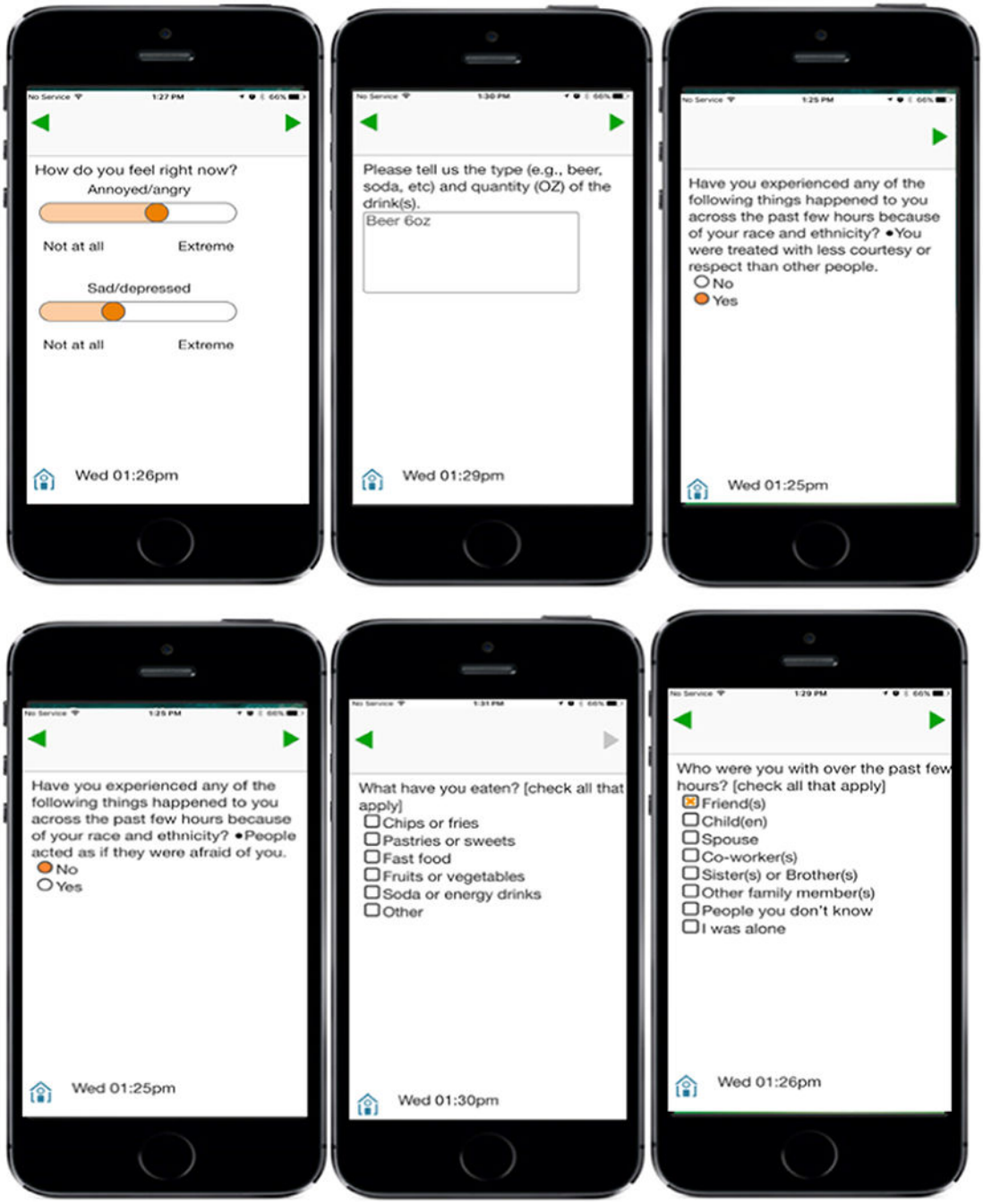

FIGURE 2.
Examples of ecological momentary assessment [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1

Example of EMA and salivary biomarkers daily measurement schedule

	Weekdays
Waking	Saliva (scheduled reminder)
Waking +30 min	Saliva (scheduled reminder)
9:00 am -11:30 am	EMA (random)
12:00 p.m.–2:00 p.m.	EMA (random)
3:00 p.m.–5:00 p.m.	EMA (random)
Before dinner	Saliva (scheduled reminder)
5:30pm–7:30 p.m.	EMA (random)
8:00pm–9:30 p.m.	EMA (random)
Bedtime	Saliva (scheduled reminder)

Abbreviation: EMA, ecological momentary assessment.

TABLE 2

Summary of measures and methods

Constructs (measures)	Sample items (data collection methods)
Individual characteristics (paper-pencil surveys)	
Sociodemographics	Age, sex, income, education
Charlson Comorbidity Index (20 items)	Checklist (e.g., hypertension, diabetes, chronic kidney disease)
Clinical data	Body mass index (BMI), blood pressure, body composition, and current medication
Alcohol Use Disorders Identification Test	"How many drinks containing alcohol do you have on a typical day when you are drinking?"
Smoking	"What is the usual number of cigarettes you smoke in a day?"
Biological stress-immune-inflammatory markers (hair and saliva samples)	
Hair cortisol (stress)	A small amount of hair (30 μg), 3 cm in length reflects cortisol secretion over the past 12 weeks
Salivary biomarkers (4×/day for 4 days): stress and inflammation	Cortisol, salivary alpha-amylase (sAA), C-reactive protein (CRP), secretory immunoglobulin A (S-IgA), and interleukin-6 (IL-6)
Racial discrimination, lifestyle behaviors, affective states, and social/environmental contexts (EMA 5×/day for 7 days and accelerometer for 7 days)	
Experiences of discrimination	"Over the past few hours, have you experienced any of the following things because of your race/ethnicity?" "You were treated with less courtesy or respect than other people." (Yes/No)
Racial microaggression	"Think about your experiences with race and ethnicity over the past 1–2 hr. How much do you disagree or agree with following statements? People treat me as if I were a criminal." (1 = *strongly disagree* to 7 = *strongly agree)*
Lifestyle behaviors	"Right before the phone went off, were you engaged in any of following activities?" [check all that apply]—e.g., smoked, physical activity, eaten something, had drinks, etc.
Affective states	"How (tense/anxious, emotionally upset, stressed, lonely/alone, annoyed/angry, sad/depressed, and discouraged/frustrated, happy) do you feel right now?"
Social/environmental context	"Where were you over the past few hours?" and "Who were you with over the past few hours?"
Hip accelerometer and paper diary (for 7 days)	Total wear-time (min), daily wear-time (hr/day), moderate–vigorous physical activity (min/day), and sedentary time (hr/day)
Process evaluation measures (data on EMA, saliva, and accelerometers and surveys)	
Feasibility	– A retention rate (the percentage of participants who completed the EMA survey at least 3×/day and on 5 of the possible 7days of EMA data collection): >80% – Response/adherence rates for EMA responses, saliva collections, and accelerometers: >70%.
Acceptability	(a) Overall satisfaction with the study protocols, (b) challenges in saliva collection and storage, and (c) willingness to participate in a similar future study using a 5-point Likert scale, with greater values indicating more satisfaction. Two open-ended questions on their experiences in EMA and the EMA frequency.

Abbreviation: EMA, ecological momentary assessment.

TABLE 3

Participants characteristics (n = 12)

Category	Mean or *N*	*SD* or %
Age (years)	43.42	7.73
Woman	8	66.63
Working full-time	10	83.3
Working part-time	2	16.7
Annual income		
<$ 39,999	2	16.7
$40,000–$59,999	6	50.0
$60,000–$79,999	1	8.3
$80,000–$99,999	2	16.7
>$100,000	1	8.3
Education		
Some high school	1	8.3
Vocational/technical school	1	8.6
Some college	5	41.7
College graduate	5	41.7
Body mass index (BMI) (kg/m^2)	34.19	11.41
18.5–24.9 (normal)	3	
25–29.9 (overweight)	4	
30–34.9 (class I obesity)	0	
35–39.9 (class 2 obesity)	1	
>40 (class 3 obesity)	4	
Blood pressure, systolic (mmHg)	123.0	16.19
Blood pressure, diastolic (mmHg)	82.50	13.0
Total body fat (%)	38.85	14.26
Visceral fat (%)	10.83	5.34
Smoking		
No	11	91.7
Alcohol consumption		
Never	3	25
Monthly or less	5	41.7
2–4 times a month	4	33.3
Moderate–vigorous physical activity (MVPA)[a] (min/day)	18.5	16.3

Category	Mean or *N*	*SD* or %
Sedentary time[a] (hr/day)	8.6	2.12

[a]Measured by accelerometers ($n = 10$).

TABLE 4

The responses or adherence to the data collection protocols ($n = 12$)

Data collection protocols	Mean (*SD*), or frequency (%, *n*)
A 7-day EMA response rate (total 35 surveys) (%)	82.8 (16.12)
Number of responses to EMA per day (max: 5 surveys/day)	3.96 (1.21)
Saliva collection adherence (4×/day for 4 days, 16 samples) (%)	100
Participants who wore an accelerometer 6 out of 7 days	83.3% (10)
Valid accelerometer data (≥10 hr/day wear-time) at least 4 days out of 7 days	83.3% (10)

Abbreviations: EMA, ecological momentary assessment; *SD*, standard deviation.