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Real-time subjective assessment of psychological stress: Associations with objectively-measured physical activity levels

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ABSTRACT

Psychosocial stress may be a factor in the link between physical activity and obesity. This study examines how the daily experience of psychosocial stress influences physical activity levels and weight status in adults. Temporally ordered relationships between sedentary, light, and moderate-to-vigorous physical activity levels and real-time reports of subjective psychosocial stress levels are reported. Adults (n = 105) wore an accelerometer and participated in an ecological momentary assessment (EMA) of stress by answering prompts on a mobile phone several times per day over 4 days. Subjective stress was negatively related to sedentary activity in the minutes immediately preceding and immediately following an EMA prompt. Light activity was positively associated with a subsequent EMA report of higher stress, but there were no observed associations between stress and moderate-to-vigorous activity. Real-time stress reports and accelerometer readings for the same 4-day period showed no association. Nor were there associations between real-time stress reports and weight status.

1. Introduction

Obesity affects nearly one in three adult Americans, with even higher prevalence among those who are socially and economically disadvantaged (Centers for Disease Control and Prevention & Behavioral Risk Factor Surveillance System (BRFSS), 2015; Flegal, Carroll, Kit, & Ogden, 2012). Obesity is associated with serious chronic health conditions including heart disease, diabetes, cancer, and osteoarthritis (Centers for Disease Control and Prevention, 2012), making it one of the largest contributors of excess mortality and morbidity in the United States today. Weight gain, at the individual level, is fundamentally caused by consuming more calories than one burns over a given time period (Hall et al., 2012).

However, current research suggests that this "energy balance equation" might have other important inputs. For example, chronic exposure to psychosocial stress has been implicated as a factor in excess weight, abdominal fat deposition, and weight gain over time (Bjorntorp, 2001; Block, He, Zaslavsky, Ding, & Ayanian, 2009; Harding et al., 2014; Iversen, Strandberg-Larsen, Prescott, Schnohr, & Rod, 2012; Rod, Gronbaek, Schnohr, Prescott, & Kristensen, 2009; Torres & Nowson, 2007). Chronic psychosocial stress is defined as exposure to social conditions sufficiently demanding that they threaten homeostasis on a consistent basis over a long duration (Lazarus, 1966; Schneiderman, Ironson, & Siegel, 2005). Examples of such conditions include adverse life events, work stress, low socioeconomic status leading to daily worry and hassles, and exposure to racial discrimination (Schneiderman et al., 2005; Tarani, Eric, & Michael, 2006; Williams, Neighbors, & Jackson, 2003). Such events lead to repeated activation of a biological stress response, often known as the "fight or flight" reaction, which involves the release of stress hormones and other physical responses intended to maintain homeostasis during a period of duress.

Paradoxically, although the fight or flight response prepares the body for bursts of physical activity (such as fighting or fleeing), both acute and chronic stress have been linked to *suppressed* physical activity in the long run (Barrington, Ceballos, Bishop, McGregor, & Beresford, 2012; Bartolomucci et al., 2003; Chandola et al., 2008;

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Laugero, Falcon, & Tucker, 2011). Reduced activity level is thought to disrupt the energy balance equation, over time leading to weight gain. A review by Stults-Kolehmainen and Sinha found support for the general conclusion that both chronic and acute psychosocial stress inhibit physical activity, leading to more time spent in sedentary behavior (2014).

However, there is some countervailing evidence suggesting that under certain circumstances, stress can promote physical activity—as when people engage in physical activity as a stress coping behavior (Stults-Kolehmainen & Sinha, 2014). Substantial evidence points to physical activity as being effective at ameliorating perceived stress and anxiety (Norris, Carroll, & Cochrane, 1992; Salmon, 2001; Schnohr, Kristensen, Prescott, & Scharling, 2005; Skirka, 2000; Stults-Kolehmainen & Sinha, 2014; Wipfli, Rethorst, & Landers, 2008) and reducing the longer-term negative health consequences of chronic stress (Gerber & Puhse, 2009; Rethorst, Wipfli, & Landers, 2009; Stults-Kolehmainen & Sinha, 2014). People who are already physically active are more likely to exercise to cope with stress, hinting that the stress-activity-obesity relationship is moderated by habitual behaviors, predisposition for physical activity, and other individual factors (Stults-Kolehmainen & Sinha, 2014).

Exposure to psychosocial stress is frequently assessed using a retrospective survey approach, in which respondents are asked to recall their experience of stress over some defined recent time period. Ecological Momentary Assessment (EMA) is a data collection method that uses repeated, *in-situ* measurement to address some limitations of retrospective assessment techniques (Stone & Shiffman, 1994). For example, the lookback window, survey setting and the time of day that a survey is given may affect the information recalled and reported on traditional paper-and-pencil retrospective recall survey instruments, limiting the generalizability of such data (Shiffman, Stone, & Hufford, 2008). People tend to recall more recent events more accurately and strongly than more temporally distal events, leading them to provide reports that are driven by recent events (Cohen, Kessler, & Gordon, 1995). Recall biases may also be introduced by individual-level coping mechanisms, education, and even fluctuations in mood (Carels, Douglass, Cacciapaglia, & O'Brien, 2004). In contrast, EMA data are captured *in situ*—that is, in the place and time that the events occur—minimizing recall and setting biases (Shiffman et al., 2008). EMA is able to capture moment-to-moment differences in experience and responses, a characteristic that is lost in recalled reports (Stone et al., 1998). EMA contributes critical information about psychosocial states and moment-to-moment changes in behavior, and may have a stronger correlation with predicting maladaptive behaviors than does recalled data (Anestis et al., 2010). Steptoe et al. found that EMA detected significant relationships between positive affect and post-stress recovery, as well as fluctuations in cortisol levels over the course of a day—a biomarker of stress—where retrospective survey techniques failed to find relationships (2007). An EMA approach to stress and physical activity may be able to broaden our understanding of daily variation in stress and behavioral changes in response to stress, and ultimately contribute to our understanding of the stress-activity-obesity link. In this work, we also exploit real-time physical activity data captured from a wearable device. Accelerometer data, similar to EMA data, are less subject to the biases introduced by self-reporting, and are thus preferable for valid measurement of moderate-to-vigorous physical activity and sedentary activity (Pedisic & Bauman, 2015).

Although stress levels normally fluctuate throughout the day and over the course of a typical week (Dunton, Atienza, Castro, & King, 2009), to date there has been little work exploring real-time variation in perceived stress and its relationships with health behaviors, including activity level. Because physical activity self-efficacy can vary over short time periods (Dunton, Huh, Castro, Hedeker, & King, 2013; Pickering et al., 2016), within-person variation—or variation in response to specific stimuli throughout the day—may be critical to understanding how people make decisions related to activity behavior. In a pilot study, Dunton et al. showed that negative affect—a global measure which included subjective stress—was associated with reduced physical activity later in the same day (2009). The present study extends the literature linking within-person psychosocial stress to physical activity by focusing on subjective reports of stress, as measured by EMA, and the relationship between stress and time spent in subsequent sedentary activity, light activity, or moderate-to-vigorous physical activity. We address two questions using an adult population: is an EMA measure of stress associated with sedentary, light, and moderate-to-vigorous physical activity level in real-time? And second, is stress as reported by EMA related to overall sedentary, light, and moderate-to-vigorous physical activity levels and weight status?

2. Subjects and methods

2.1. Data and participants

The primary sample consisted of 120 community-dwelling adults living in and around Chino, California (a suburb of Los Angeles). This study used baseline (Wave 1) data from the Project on Measuring our Behaviors and Living Environments (Project MOBILE) (Dunton, Liao, Kawabata, & Intille, 2012). Participants were recruited to the study through posters, letters sent to home addresses, and referrals from a parent study known as Healthy PLACES. Participants were at least 28 years of age and able to answer EMA surveys on a study-provided mobile phone during the day, including at work where applicable. Individuals were excluded if they did not speak and read English fluently or had a high annual household income (>US $210,000). Because the goals of the larger study were related to increasing physical activity behavior, participants were also excluded if they were already meeting the physical activity guideline of 150 min per week, or had physical limitations that made them unable to exercise. Participants were compensated up to $50 for participating in the study. This research was reviewed and approved by the Institutional Review Board at the University of Southern California.

2.2. Procedure

During a baseline data collection session, participants self-reported age, sex, ethnicity, and annual household income. At that time, they also completed a traditional paper-and-pencil retrospective report of stress, mood, and cognition. Anthropometric measures were collected by trained data collectors at the time of the baseline survey. Weight was recorded to the nearest 0.1 kg using a digital scale (Tanita WB-110A), and height was recorded to the nearest 0.1 cm using a professional stadiometer (PE-AIM-101). Waist circumference was measured in triplicate and recorded to the nearest 0.1 cm.

Project MOBILE used EMA to capture participants' current stress state several times per day over a 4-day period. Participants were provided with an HTC Shadow mobile phone (T-Mobile USA, Inc.) equipped with a customized software program (app) based on the MyExperience platform (myexperience.net, 2007). The app was programmed to display a short electronic survey to which participants responded using the device's touch screen. Data were stored on the device and later downloaded by the research team. Participants were trained in how to use the device and complete the survey, and completed a guided practice assessment prior to the start of the study period. Participants were asked to carry the phone