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Greater variability in daily physical activity is associated with poorer mental health profiles among obese adults

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ABSTRACT

Research is inconclusive about whether physical activity (PA) should be performed every day or performed less frequently but in longer bouts to obtain mental health benefits. The current study examined the extent to which day-to-day variability in PA is associated with adults' mental health, and if this association differed by Body Mass Index (BMI). Adults (N = 116) completed three waves of data collection (each lasting 4 days) during which participants completed a questionnaire assessing mental health (life satisfaction, depressive symptoms, perceived stress), wore a waist accelerometer, and had height and weight measured. This study employed a novel two-stage data analysis approach using the standalone program MIXWILD. The first-stage model partitioned mean level as well as between-subject and within-subject variances in daily PA by estimating a random location (subject-level mean) and a random scale (subject-level variability) for daily PA. In the second-stage, these random subject effects for daily PA along with their interactions with BMI were used as predictors for subject-level mental health outcomes. Associations between subject-level variability in daily PA and mental health outcomes significantly differed depending on adults' BMI (life satisfaction: $\beta = -0.05$, $p < 0.05$; depressive symptoms: $\beta = 0.03$, $p < 0.05$; perceived stress: $\beta = 0.04$, $p < 0.01$). Greater day-to-day variability in PA was associated with poorer mental health in adults with higher BMI values as compared to adults with lower BMI. For individuals with high BMI values, inconsistent activity patterns may have consequences that diminish mental health. Strategies that promote consistency in daily PA may be useful for individuals with high BMI to enhance mental health.

1. Introduction

Adults that engage in regular physical activity are less likely to develop many chronic diseases and are considered to be healthier compared to adults that do not regularly engage in physical activity (Physical Activity Guidelines Advisory Committee, 2008). The U.S. Federal Physical Activity Guidelines outline specific recommendations regarding the duration and intensity of aerobic physical activity accumulated across the week to gain substantial health benefits (i.e., 150 min of moderate intensity physical activity, 75 min of vigorous-intensity or some combination of both) (Physical Activity Guidelines Advisory Committee, 2008). However, less specific recommendations are given regarding the frequency of aerobic physical activity within these guidelines. Regarding frequency, the guidelines merely state that, "aerobic physical activity should preferably be spread throughout the week." Other organization-level guidelines such as those issued by the American College of Sports Medicine and American Heart Association, do specify frequency of physical activity, stating that exercise should be performed on five days each week (Haskell et al., 2007). This ambiguity across guidelines leads to questions about the ways in which adults accrue physical activity across the week, and how day-to-day stability or variability in daily physical activity have

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implications for aspects of physical and mental health.

Research regarding the stability or variability in daily physical activity and subsequent associations with aspects of physical health such as chronic disease and mortality is equivocal. For instance, Lee, Sesso, Oguma, and Paffenbarger (2004) examined data from the Harvard Alumni Health Study and found that for men who sporadically engaged in physical activity (i.e., 1–2 times/week) but met recommended levels of physical activity (i.e., ≥1,000 kcal/week of energy expenditure), their relative risk of mortality was not significantly different compared to men who were considered inactive (i.e., <500 kcal/week of energy expenditure) after adjusting for relevant risk factors. More recently in a longitudinal cohort study, O'Donovan, Lee, Hamer, and Stamatakis (2017) found that adult men and women who sporadically engaged in physical activity and did not meet recommended levels of physical activity (i.e., reporting <150 min/week in moderate-intensity and <75 min/week in vigorous-intensity activities) as well as individuals who sporadically engaged in physical activity and did meet recommended levels of physical activity (i.e., reporting ≥ 150 min/week in moderate-intensity or ≥ 75 min/week in vigorous-intensity activities from 1 or 2 sessions), both experienced significant decreases in risk of all-cause mortality compared to inactive adults (i.e., reporting no moderate- or vigorous-intensity activities). These findings indicate that perhaps sporadic participation in physical activity (i.e., having day-to-day variability) is not necessarily more maladaptive to physical health than consistently engaging in physical activity every day.

Even less is known regarding the extent to which stability or variability in daily physical activity has implications for mental health. The majority of research linking physical activity to various mental health outcomes has focused on examining between-person effects of physical activity on mental health outcomes (i.e., how do more or less active people differ in terms of their overall mental health profiles?) (e.g., Fox, 1999; Penedo & Dahn, 2005). Isotemporal substitution models suggest that between-person differences in health behavior patterns are associated with between-person differences in mental health profiles such as lower perceived stress, greater quality of life, and improved self-regulation and executive functioning (e.g., Buman et al., 2010; Fanning et al., 2017). More recently, researchers have investigated within-person associations between physical activity and mental health outcomes (i.e., how does being more or less physically active than usual on a particular day influence mental health on that same day?). For example, Hyde, Conroy, Pincus, and Ram (2011) found that on days when college students engaged in more physical activity than was typical for them, they experienced more pleasant-activated affect on those days. Additionally, Maher and colleagues found that on days when adults spent more time being physically active than was typical for them, they experienced greater life satisfaction on those days (Maher & Conroy, 2017; Maher, Pincus, Ram, & Conroy, 2015; Maher et al., 2013). While research examining these within-person day-level effects aid in our understanding of more acute relations between physical activity and mental health, existing research does not reveal the extent to which the degree of stability or variability in daily physical activity at the subject-level (i.e., the degree to which a person experiences intra-individual variability or within-subject variability in daily physical activity) is associated with subject-level differences in overall, trait-level mental health characteristics.

The extent of stability or variability in day-to-day physical activity could influence mental health for various reasons. First, engaging in regular physical activity is associated with enhanced efficacy beliefs regarding personal control among adults (e.g., Elavsky et al., 2005; McAuley et al., 2008; Motl et al., 2005). Therefore, individuals who consistently engage in physical activity may feel more capable and competent to effectively navigate the events, stressors, and hassles of everyday life, thereby resulting in a better mental health profile compared to those who engage in physical activity more erratically (Maher et al., 2015; McAuley et al., 2008). Whereas for individuals who experience more day-to-day variability in their physical activity, days when physical activity is low (or lower than usual) may reflect an inability to overcome barriers and a lack of personal control. Greater day-to-day variability in physical activity may lead individuals to experience these negative beliefs more often, adversely impacting mental health. Second, acute bouts of physical activity are linked to transient changes in affective and physical feeling states (e.g., Liao, Shonkoff, & Dunton, 2015; Reed & Ones, 2006), which if accumulated over time through frequent and consistent bouts of behavior are likely to enhance mental health profiles. However, no known studies have examined how subject-level variability in daily physical activity may predict aspects of one's subject-level, or trait-level, mental health.

Moreover, it is possible that Body Mass Index (BMI) may influence the strength of associations between physical activity patterns and mental health outcomes. First, numerous studies have linked obesity to poorer mental health profiles (Onyike, Crum, Lee, Lyketsos, & Eaton, 2003; Zhao et al., 2009). For instance, data from the National Health and Nutrition Examination Survey revealed that adults with depression were more likely to be obese compared to adults without depression (Pratt & Brody, 2014). Furthermore, evidence suggests that obese individuals experience greater levels of discomfort while exercising and fewer affective benefits following a bout of exercise compared to their normal weight counterparts (Ekkekakis, Lind, & Vazou, 2010; Zdziarski, Wasser, & Vincent, 2015). This suggests that obese individuals who engage in physical activity inconsistently may be more susceptible to these affective decrements and result in diminished mental health profiles. Finally, obese individuals face can societal stigma, and failure to consistently engage in physical activity may elicit self-conscious emotions (e.g., shame) associated with the stigma of being obese (Myers & Rosen, 1999; Puhl & Heuer, 2010). The extent to which associations between day-to-day variability in physical activity and mental health differ depending on BMI has not been explored.

The use of accelerometery provides intensive longitudinal data of physical activities accrued within the context of everyday life. As a result, this intensive longitudinal data provides a rich data source for modeling variance in subject-level mean and variability parameters of daily physical activity. Mixed-effects location scale modeling is an extension of multilevel models that can aggregate a time-varying variable, such as daily physical activity, into subject-level mean (e.g., time spent engaged in physical activity, on average, across days) and intraindividual variability (e.g., the degree to which time spent in physical activity is erratic across days) indicators (Hedeker & Nordgren, 2013). This allows intraindividual variability in daily physical activity to be modeled as a subject-level predictor of person-level outcomes such as indicators of mental health, along with traditional predictors such as mean level of daily physical activity.

1.1. The present study

The present study explored associations between subject-level variability in daily physical activity and trait-like mental health outcomes across adults of different BMI values. A broad constellation of both positive (i.e., life satisfaction) and negative (i.e., depressive symptoms, perceived stress) global indicators of mental health served as outcomes in this study. These mental health outcomes were chosen to align with previous research on associations between physical activity and mental health at the between-person (i.e., depressive symptoms, perceived stress) and within-person