Daily Life Satisfaction in Older Adults as a Function of (In)Activity

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Results. Separate multilevel models were tested for self-reported and objectively measured behavioral data. In the model using objectively measured behavioral data, life satisfaction was (a) negatively associated with sedentary behavior at the within-person level and unassociated with sedentary behavior at the between-person level and (b) unassociated with physical activity at either the between-person or within-person level. In the model using self-reported behavioral data, life satisfaction was (a) unassociated with sedentary behavior at either the between-person or within-person level and (2) positively associated with physical activity at the within-person, but not at the between-person, level.

Discussion. Results indicated that daily deviations in objectively measured sedentary behavior and self-reported physical activity have implications for older adults' well-being. Interventions designed to enhance well-being and quality of life in older adults should consider targeting daily changes in total sedentary behavior and daily changes in the volume or frequency of physical activity.

Keywords: Exercise | Intraindividual | Sedentary behavior | Sitting | Well-being

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Original Research Report

Daily Life Satisfaction in Older Adults as a Function of (In) Activity

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Keywords: Exercise—Intraindividual—Sedentary behavior—Sitting—Well-being

Excessive sedentary behavior is associated with poor psychological health in older adults; however, there is little work investigating relations between sedentary behavior and life satisfaction in this population. Life satisfaction may be particularly relevant for older adults because it reflects the extent to which older adults are able to preserve quality of life in the face of advancing age (Rejeski & Mihalko, 2001). Additionally, life satisfaction is strongly associated with mortality in old age, suggesting that life satisfaction is not only a desired subjective feeling but reflects a person's health (St John, Mackenzie, & Menec, 2015). Thus, life satisfaction is an important outcome in and of itself and can serve as an indicator of successful aging (Cho, Martin, & Poon, 2015). This study examined associations between sedentary behavior, physical activity, and life satisfaction.

Life Satisfaction

Life satisfaction is conceptualized as a cognitive evaluation of one's life and represents how well a person's current self aligns with her or his ideal self. Strategies for preserving and promoting life satisfaction among older adults are important given the graying of America and society's emphasis on not just adding years but on adding quality years to life (West, Cole, Goodkind, & He, 2014). Understanding the association between health behaviors, such as sedentary behavior and physical activity, and life satisfaction may reveal new approaches to promoting successful aging in older adults.

Influences on life satisfaction can be framed as either between- or within-person (Maher et al., 2013). Top-down influences reflect stable individual differences that exert an influence on usual levels of life satisfaction (i.e., between-person process), whereas bottom-up influences reflect dynamic behaviors or states that exert an influence on daily life satisfaction (i.e., within-person process; Diener, 1984).

Life Satisfaction and Health Behaviors

Sedentary behavior and physical activity may exert a between- or within-person influence, or both, on life satisfaction. Sedentary behavior and physical activity are health behaviors with established between-person associations with global indicators of well-being (de Rezende, Rey-López, Matsudo, & do Carmo Luiz, 2014; Physical Activity Guidelines Advisory Committee, 2008; Teychenne, Ball, & Salmon, 2010). Greater well-being is associated with lower usual levels of sedentary behavior and higher usual levels of physical activity. These associations are likely mediated by individual differences in health (St John, Tyas, & Montgomery, 2013; Wilhelmson, Fritzell, Eklund, & Dahlin-Ivanoff, 2013).

Associations between daily sedentary behavior, physical activity, and indicators of well-being (i.e., with-person processes) in older adults are less established. It may be that daily sedentary behavior is associated with life satisfaction through affective processes and daily physical activity is associated with life satisfaction through revitalization processes (Gauvin, Jack, & Reboussin, 2000; Puetz, O'Connor, & Dishman, 2006; Schwerdtfeger, Eberhardt, Chmitorz, & Schaller, 2010).

Distinguishing between Sedentary Behavior and Physical Activity

Sedentary behavior and physical inactivity are conceptually different with the former referring to waking activities that take place in a seated or reclined posture and expend little energy and the latter referring to a lack of moderate- or vigorous-intensity physical activity (Marshall & Ramirez, 2011; Owen, Healy, Matthews, & Dunstan, 2010). This distinction between sedentary behavior and physical activity is critical because (a) physical activity can displace sedentary behavior and confound interpretations of associations between sedentary behavior and life satisfaction and (b) it is possible that each behavior has a unique effect on life satisfaction.

Life Satisfaction and Sedentary Behavior

Withall and colleagues (2014) previously investigated associations between sedentary behavior and life satisfaction in older adults and found a null between-person association. However, this study only accounted for associations between usual levels of sedentary time and life satisfaction (i.e., a between-person association) and failed to account for associations between daily levels of sedentary behavior and life satisfaction (i.e., a within-person association). Life satisfaction has been shown to vary from day to day in populations across the adult life span, and findings from these studies suggest that daily life satisfaction is predicted by day to day changes in sedentary behavior and physical activity (Maher et al., 2013; Maher, Doerksen, Elavsky, & Conroy, 2014; Maher, Pincus, Ram, & Conroy, 2015). For example, Maher and colleagues (2014) found that university students experienced lower life satisfaction on days when they were more sedentary than was typical for them (i.e., a within-person association); however, life satisfaction did not differ between people who, on average, were more or less sedentary (i.e., a null between-person association; Maher et al., 2014).

There has yet to be a study to examine associations between sedentary behavior and life satisfaction at the between- and within-person level, simultaneously, in older adults across both self-reported and objective measures of behavior. Addressing this gap in the literature is important because older adults spend such a large amount of time in sedentary activities and life satisfaction can serve as an indicator of their success in the aging process (Cho et al., 2015; Harvey, Chastin, & Skelton, 2015; Matthews et al., 2008).

Life Satisfaction and Physical Activity

Cross-sectional and prospective studies examining the between-person association between physical activity and life satisfaction in older adults find that more active people generally tend to experience greater life satisfaction compared with less active peers (e.g., Elavsky & McAuley, 2005; Elavsky et al., 2005). Only one study to date has simultaneously investigated associations between physical activity and life satisfaction at both the between- and within-person level in older adults (Maher et al., 2015). Older adults experienced greater life satisfaction if they engaged in greater usual self-reported physical activity than their peers, and on days when they were more physically active than was typical for them. That study did not account for sedentary behavior, so it is not yet clear whether associations between physical activity and life satisfaction are due to overall physical activity volume itself or the displacement of sedentary behavior (Powell, Paluch, & Blair, 2011).

The Present Study

To investigate the between- and within-person associations between sedentary behavior, physical activity, and life satisfaction, a 14-day daily diary study was conducted. This study employed both daily diary and ambulatory monitoring techniques. Both daily and usual sedentary behavior were hypothesized to be negatively associated with life satisfaction across both self-reported and objectively measured behavior. Daily and usual physical activity were hypothesized to be positively associated with life satisfaction across both measures of behavior. In testing these hypotheses, we statistically controlled for potential within-person confounds including daily physical symptoms, day-of-week, time-of-year, and time-in-study, and potential between-person confounds such as overall physical symptoms, sex, age, and body mass index (BMI).

Method

Participants

Older adults (n = 114) expressed an interest in participating in the study. Inclusion criteria included (a) being 60 years or older and (b) self-reported sitting for an average of ≥8 hours/day. An average of ≥8 hours/day of sitting was chosen as an inclusion criterion because this level of behavior is (a) associated with increased risk for a variety of negative health consequences in sedentary behavior and (b) consistent with population data regarding the majority of older adults' sedentary behavior (Biswas et al., 2015; de Rezende et al., 2014; Harvey et al., 2015; Matthews et al., 2008). Exclusion criteria included (a) having been diagnosed by a physician as having dementia or Alzheimer's disease or (b) reporting any deficit in functional mobility as assessed by the walking and transferring subscales of the Instrumental Activities of Daily Living Scale (Lawton & Brody, 1969). The final sample comprised 67 women and 33 men. The sample was almost exclusively White (99%) and non-Hispanic (99%). The mean age of the sample was 74.2 years (SD = 8.2; range: 60–89 years). Based on World Health Organization cutoffs for body mass index (M = 27.3 kg/m^2, SD = 5.3), participants were relatively evenly split between normal weight (38.6%), overweight (36.7%), and obese (23.7%).

Procedures

At an initial lab session, participants provided consent and completed a questionnaire regarding demographic information (i.e., age, sex, race, ethnicity, height, and weight). Next, participants were trained on how to use a tablet computer to answer a brief questionnaire at the end of each day. Participants were also trained on how to affix and wear a waterproofed ActivPAL3 activity monitor on the front of their thigh (3–4 inches above the knee). For the next 14 days, participants answered a questionnaire at the end of each day on their tablet and wore their activity monitor. On Day 14, participants returned the study equipment. Study procedures were approved by the local institutional review board.

Measures

Life Satisfaction

Daily life satisfaction was assessed using a single item from the Satisfaction with Life Scale (Diener, Emmons, Larsen, & Griffin, 1985) modified for daily administration (i.e., "I was satisfied with my life today"). Participants provided ratings using a slider-type interface, location along which is digitally coded on a 0 (*strongly disagree*) to 100 (*strongly agree*) scale. In an 8-day daily diary study, Maher and colleagues (2013) administered the complete 5-item Satisfaction with Life Scale and found that this item was the most strongly associated with the latent life satisfaction factor.

Objective Sedentary Behavior and Physical Activity

Objectively measured sedentary behavior and physical activity were assessed using ActivPAL3 activity monitors (Physical Activity Technologies, Glasgow, Scotland), which have been validated in older adults (Grant, Dall, Mitchell, & Granat, 2008). The ActivPAL3 monitor uses an inclinometer and accelerometer to measure posture and activity, respectively, and then classifies the time spent sitting or lying, standing, and stepping. Time spent sleeping was subtracted from daily objectively measured sedentary behavior to determine the amount of time each day spent sitting or lying down while awake. Physical activity was defined as time spent stepping. The ActivPAL3 activity monitor does not contain a visual display, so there was no behavioral feedback. Data were screened to identify valid days. Following established conventions, a valid day of recording consisted of ≥10 hours of valid waking wear time with participant logs and accelerometer data (i.e., every period of 60 consecutive minutes of zeros) used to determine non-wear time.

Self-Reported Sedentary Behavior and Physical Activity

Daily self-reported sedentary behavior was assessed using a 9-item scale, which features domain-specific sedentary activities included in other validated measures of sedentary behavior in older adults (i.e., watching TV, using the computer, reading, socializing with friends, in transit, completing hobbies, doing paperwork, eating, or any other activities; Gardiner et al., 2011; Visser & Koster, 2013). Participants were instructed to report the amount of waking time they spent sitting or lying down while engaged in each of those domain-specific sedentary activities (e.g., "Today, how much time in total did you spend sitting or lying down while watching television or videos/DVDs?"). In the event that participants were engaged in more than one sedentary activity (e.g., sitting while driving and socializing with a friend) at a given time, participants were instructed to assign that time to whichever they considered the main sedentary activity. Responses to these nine items were summed to create daily total sedentary behavior scores. Daily self-report physical activity was assessed using a modified version of the International Physical Activity Questionnaire (IPAQ), a validated measure of older adult physical activity (Grimm, Swartz, Hart, Miller, & Strath, 2012). Participants were prompted with a definition, examples, and a minimum duration of activity (i.e., 10 min) and then reported the time spent engaged in walking and moderate- and vigorous-intensity physical activity (e.g., "How much time did you spend walking today?"). Standard scoring procedures for the IPAQ were used to convert duration of reported activities into metabolic equivalents (METs; Sjöström et al., 2002, 2005).

Physical Symptoms

Physical symptoms were assessed using a modified version of the physical symptoms checklist (Larsen & Kasimatis, 1991). Participants were prompted with examples of each physical symptom and then rated four items corresponding to the severity of major symptoms (i.e., musculoskeletal, gastrointestinal, cold and flu, and cardiorespiratory) on a 0 (*not at all*) to 100 (*very much*) scale that used a slider-type interface (e.g., "How would you rate the severity of these musculoskeletal symptoms today?"). Responses were weakly-to-moderately correlated (rs = .23–.43) and not internally consistent (α = .56); therefore, we included these four items separately in our models.

Temporal Processes

First, to control for the possibility that motivation or behavior changed as a result of, or was reactive to, participating in the study we created a within-person variable representing *exposure to the protocol*. The exposure variable accounted for the day in study (Godin, Bélanger-Gravel, Amireault, Vohl, & Pérusse, 2011). Second, we created six dummy variables representing the days of the week to account for possible effects of the *social calendar*. Saturday served as the reference day because life satisfaction for this sample was highest on that day.

Data Analysis Plan

Multilevel models (e.g., Snijders & Bosker, 1999) were used to examine associations at the between- and within-person level while accounting for the nested structure of the data. All models were estimated using SAS 9.3 PROC MIXED (Littell, Milliken, Stroup, & Wolfinger, 1996) with restricted maximum likelihood estimation, treating the small amount of incomplete data as missing at random. Complete self-reported data were available on all study days, resulting in a 14-day sample of behavior and well-being. Because participants attended the initial lab session at various times on Day 1 of the study, complete objectively measured data were not available on the first day of the study resulting in a 13-day sample of objective behavior.

Data Preparation

Daily ratings of predictor variables (e.g., sedentary behavior) were aggregated and person centered to separate and simultaneously test between- and within-person associations (Bolger & Laurenceau, 2013; Enders & Tofighi, 2007). For example, person *i*'s usual sedentary behavior ($Usual\ Sedentary\ Behavior_i$) was calculated as the within-person mean of her daily sedentary behavior across days, and daily sedentary behavior ($Daily\ Sedentary\ Behavior_{di}$) was calculated as the deviation of day *d*'s score from her usual sedentary behavior (i.e., cluster-mean centering; Enders & Tofighi, 2007). As such, the within-person mean scores across the 14 days differentiate between more or less sedentary *people*, and, daily deviations differentiate more or less sedentary *days*. Usual and daily physical activity and physical symptoms were also calculated this way. Age and BMI were grand-mean centered, and exposure to study was cluster-mean centered.

Multilevel Models

In the multilevel models used to test hypotheses, daily sedentary behavior, daily physical activity, daily musculoskeletal symptoms, daily gastrointestinal symptoms, daily cold/flu symptoms, daily cardiorespiratory symptoms, day of the week, and the sequence of the day in the study represented within-person influences on daily life satisfaction. The slope associated with daily sedentary behavior was treated as a random effect. All other within-person slopes were treated as fixed effects. Usual sedentary behavior, usual physical activity, usual musculoskeletal symptoms, usual gastrointestinal symptoms, usual cold/flu symptoms, usual cardiorespiratory symptoms, sex, age, and BMI represented between-person influences on daily life satisfaction. Separate models using daily self-reported and objectively measured behavior to predict life satisfaction were estimated.

Results

Participants provided self-reported data on a median of 14 days (M = 13.5, SD = 1.2) for a total of 1,313 of the 1,400 possible person-days (94% response rate). Participants provided valid objectively measured data on 12 days (M = 11.9, SD = 1.5) for a total of 1,196 of the 1,300 possible person-days (92% response rate). Missing data (< 1%) were assumed to be missing completely at random.

Table 1 presents descriptive statistics and between- and within-person correlations between life satisfaction, sedentary behavior, physical activity, and control variables. On average, participants reported moderate-to-high levels of daily life satisfaction (M = 78.5 on a 0 to 100 scale). Between- and within-person correlations exhibited similar patterns. Life satisfaction had weak, negative correlations with self-reported and objectively measured sedentary behavior. Life satisfaction had weak, positive correlations with self-reported and objectively measured physical activity. Approximately half of the variance in life satisfaction as well as self-reported and objectively measured sedentary behavior was between-person variance,

Table 1. Descriptive Statistics, Correlations, and Intraclass Correlation Coefficients of Life Satisfaction, Sedentary Behavior, Physical Activity, and Other Variables of Interest

	M	*SD*	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Life satisfaction	78.5	21.5	(.45)	−.03	−.05	.02	.15	−.36	−.41	−.37	−.25
2. Daily objective sedentary behavior (min/day)	573.7	145.0	−.06	(.55)	.43	−.52	−.01	.01	−.03	.01	.04
3. Daily self-reported sedentary behavior (min/day)	636.6	219.9	−.01	.38	(.56)	−.38	−.31	.14	.01	.01	.05
4. Daily objective physical activity (min/day)	96.0	50.4	.01	−.45	−.29	(.42)	−.09	−.19	.01	−.04	−.11
5. Daily self-reported physical activity (MET · min · day^{-1})	617.9	612.5	.09	.09	.09	.10	(.11)	.23	.10	.18	.34
6. Daily musculoskeletal symptoms	23.6	27.8	−.24	.01	.09	−.11	.15	(.66)	.31	.46	.49
7. Daily cold/flu symptoms	6.1	15.5	−.22	.01	.05	−.01	.06	.24	(.44)	.66	.57
8. Daily gastrointestinal symptoms	5.9	14.4	−.17	.02	.01	−.03	.09	.30	.43	(.36)	.55
9. Daily cardiorespiratory symptoms	4.7	12.2	−.14	.02	.01	−.04	.16	.33	.37	.36	(.38)

Note: Intraclass correlation coefficients representing the proportion of between-person variance appear in parentheses on the diagonal of the correlation matrix. Coefficients below the diagonal represent correlations across days and people (i.e., within-person correlations). Coefficients above the diagonal represent correlations of intraindividual means (i.e., between-person correlations). MET = metabolic equivalent.

with the remainder driven by within-person factors and measurement error.

Unstandardized parameter estimates from the multilevel models predicting life satisfaction are presented in Table 2. Consistent with hypotheses, the model of objectively measured behavior (left column of coefficients) indicated that life satisfaction was lower on days when people were more sedentary than was typical for them; however, there was no difference in life satisfaction between more or less sedentary people. Additionally, life satisfaction did not differ between people who were more or less physically active on average or on days when people were more or less physically active than was typical for them.

Contrary to the hypothesis, the model of self-reported behavior (right column of coefficients) indicated that life satisfaction did not differ between people who reported being more or less sedentary in general or on days when people reported being more or less sedentary than was typical for them. Life satisfaction was higher on days when people reported engaging in more physical activity than was typical for them; however, life satisfaction did not differ between people who reported being more or less sedentary.

Across both objectively measured and self-reported models, life satisfaction was higher for people (a) with a higher BMI and (b) who experienced fewer musculoskeletal symptoms or fewer cold and flu symptoms on average. Life satisfaction also was higher on days when people experienced fewer musculoskeletal symptoms than was typical for them.

These multilevel models assumed that the day's health behaviors would influence end-of-day life satisfaction. However, it is also possible that a given day's sedentary behavior or physical activity may have been influenced by the previous evening's life satisfaction. This alternative temporal sequence was tested in a follow-up analysis. When testing this model, life satisfaction was (a) not associated with sedentary behavior at either the between- or within-person levels ($p > .50$) and (b) not significantly associated with physical activity at either the between- or within-person levels ($p > .36$). Thus, we concluded that the between- and within-person associations between health behaviors and life satisfaction reflect the influence of behavior on self-evaluation rather than the influence of self-evaluation on behavior.

Discussion

This study was the first to simultaneously examine between- and within-person associations of older adults' life satisfaction with sedentary behavior and physical activity. It was also the first to examine those associations with objective and self-report measures of behavior. Life satisfaction was consistently unrelated to older adults' usual levels of sedentary behavior and physical activity. Results at the daily level of analysis varied. When using objectively measured behavioral data, daily sedentary behavior was negatively associated with life satisfaction, but daily physical activity was not linked with life satisfaction. When using self-reported behavioral data, daily sedentary behavior was unrelated to life satisfaction, but daily physical activity was positively associated with life satisfaction.

Consistent with findings by Withall and colleagues (2014), between-person associations between sedentary behavior and life satisfaction were not documented in this study. The null, between-person associations between sedentary behavior and life satisfaction, across both self-report and objective measures of behavior, may reflect the relatively good health status of our sample. Participants did not have any physical limitations that prevented them from walking across a room or rising out of a chair on their own. Additionally, the average severity of physical symptoms reported by participants was relatively low. Samples that include older adults with more diverse health status may exhibit a between-person association between sedentary behavior and life satisfaction (Balboa-Castillo, León-Muñoz, Graciani, Rodríguez-Artalejo, & Guallar-Castillón, 2011; Hamer & Stamatakis, 2013).

Table 2. Multilevel Coefficients Predicting Daily Life Satisfaction

	Model 1: Objectively measured behavior	Model 2: Self-reported behavior
	Parameter estimate (*SE*)	Parameter estimate (*SE*)
Fixed effects		
Intercept, γ_{00}	48.26* (17.20)	49.97* (16.71)
Usual sedentary behavior, γ_{01}	−0.01 (0.01)	−0.01 (0.01)
Daily sedentary behavior, γ_{10}	−0.01* (0.005)	−0.01 (0.01)
Usual physical activity, γ_{02}	0.02 (0.05)	0.01 (0.01)
Daily physical activity, γ_{20}	0.01 (0.05)	0.002* (0.001)
Usual musculoskeletal symptoms, γ_{03}	−0.24* (0.07)	−0.23* (0.07)
Daily musculoskeletal symptoms, γ_{30}	−0.10* (0.03)	−0.08* (0.03)
Usual cold and flu symptoms, γ_{04}	−0.54* (0.17)	−0.47* (0.17)
Daily cold and flu symptoms, γ_{40}	−0.03 (0.04)	−0.04 (0.04)
Usual gastrointestinal symptoms, γ_{05}	−0.15 (0.21)	−0.26 (0.21)
Daily gastrointestinal symptoms, γ_{50}	0.02 (0.04)	0.02 (0.04)
Usual cardiorespiratory symptoms, γ_{06}	0.22 (0.22)	0.11 (0.23)
Daily cardiorespiratory symptoms, γ_{60}	0.05 (0.05)	−0.05 (0.05)
Sex, γ_{70}	0.13 (3.13)	−0.09 (2.89)
Age, γ_{80}	0.12 (0.18)	0.16 (0.17)
BMI, γ_{90}	0.79* (0.30)	0.61* (0.28)
Sunday, γ_{07}	−0.19 (1.67)	−0.39 (1.67)
Monday, γ_{08}	−2.08 (1.74)	−2.23 (1.65)
Tuesday, γ_{09}	−1.73 (1.74)	−1.03 (1.67)
Wednesday, γ_{010}	−0.77 (1.74)	−1.14 (1.65)
Thursday, γ_{011}	−1.55 (1.70)	−1.86 (1.66)
Friday, γ_{012}	−0.34 (1.68)	0.44 (1.66)
Day in study, γ_{013}	−0.01 (0.12)	−0.01 (0.11)
Random effects		
Variance intercept, σ^2_{u0i}	148.86* (25.70)	150.13* (25.45)
Variance sedentary behavior, σ^2_{u1i}	0.01* (0.001)	0.01* (0.001)
Residual, σ^2_{uedi}	243.68	356.20
−2LL	9,732.9	11,258.7
AIC	9,738.9	11,266.7

Notes: Unstandardized estimates and standard errors. Model 1 (left column of coefficients) regressed daily life satisfaction on objectively measured behavior, and the remaining covariates. Model 2 (right column of coefficients) regressed daily life satisfaction on self-reported behavior, and the remaining covariates. Multilevel models are based on 14 and 13 occasions nested within 100 participants for a total of 1,313 self-reported and 1,196 objectively measured observations, respectively.*$p < .05$.
−2LL = −2 log likelihood; AIC = akaike information criterion; BMI = body mass index.

Findings of null associations between usual physical activity and life satisfaction conflicted with previous findings (Maher et al., 2015). For midlife and older adults, but not emerging adults, usual levels of physical activity were positively associated with life satisfaction even after controlling for daily physical activity. That study only tested a linear age moderation term, so it is possible that midlife, and not older adults, drove that between-person association.

Additionally, the physical activity measures used in the present study differed from the measure used by Maher and colleagues (2015). That study operationalized physical activity as the number of 10+ minute bouts of physical activity engaged in each day, regardless of duration (frequency), whereas this study operationalized self-reported physical activity as the average amount of energy expended based on minutes of physical activity per day (volume). Additionally, the objective measure used in this study operationalized physical activity as time spent stepping (duration) because older adults' engage in mostly light-intensity and relatively little moderate-to-vigorous–intensity physical activity (Buman et al., 2010). More frequent physical activity may make a greater contribution than the total volume or duration of physical activity to older adults' daily life satisfaction.

Differences in the within-person association between sedentary behavior and life satisfaction may reflect ways in which self-report and objective measures capture sedentary behavior. As an objective measure of sedentary behavior, the ActivPAL3 activity monitor measures posture and movement. Self-reported measures of behavior rely on a person to accurately recall time spent sitting in various activities.

Accurately recalling health behaviors, such as sedentary behavior or physical activity, may be quite challenging for individuals at any age. Sitting is a pervasive behavior across the life span (Matthews et al., 2008). Additionally, sedentary behavior is thought to be highly habitual, so people may not be aware of how much time they sit each day (Conroy, Maher, Elavsky, Hyde, & Doerksen, 2013). Furthermore, older adults face many challenges associated with aging, including declines in executive functioning (including short-term memory, problem solving, and reasoning; Salthouse, Atkinson, & Berish, 2003) that may make it difficult for them to accurately recall their sedentary behavior or physical activity (especially lifestyle physical activity).

Findings regarding associations between sedentary behavior and life satisfaction differed across self-report and objective measures of behavior. Objective data use dual inclinometers and accelerometers to determine sitting time, which provide a more accurate estimate of sedentary behavior compared with self-report measures (Aguilar-Farías, Brown, Olds, & Peeters, 2014; Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011). The former likely represents the true association between sedentary behavior and life satisfaction. Self-report data serve as a representation of older adults' perceived time use. In this study, perceived time use in different domains of sedentary behavior is likely influenced by older adults' values, interests, and goals as well as the level of enjoyment and stimulation (Salmon, Owen, Crawford, Bauman, & Sallis, 2003). The null associations between older adults' self-reported sedentary behavior and life satisfaction found in this study likely reflected those influences on perceived time use rather than on actual sitting time. The nature of the sedentary activity may be important in understanding relations between sedentary behavior and life satisfaction. The extent to which older adults find certain sedentary activities meaningful, rewarding, or socially engaging represents an important area of research because it can identify sedentary activities that can enhance or detract from life satisfaction.

This study added to accumulating evidence that objectively measured sedentary behavior is associated with life satisfaction and that this association reflects a within-person process (Maher et al., 2014). Unlike previous studies, which only examined associations between sedentary behavior and indicators of well-being at the between-person level (e.g., Balboa-Castillo et al., 2011; Hamer, Poole, & Messerli-Bürgy, 2013; Hamer & Stamatakis, 2013; Withall et al., 2014), this study examined those associations simultaneously and revealed a significant within-person, but not between-person, association. It may be that previously documented associations between sedentary behavior and indicators of well-being at the between-person level were an artifact of unaccounted for within-person processes. The within-person association between sedentary behavior and life satisfaction may be driven by affective processes; however, affect was not assessed in this study. Therefore, future work is needed to corroborate this proposed mechanism.

This study adds to accumulating evidence that daily deviations in self-reported physical activity are associated with life satisfaction across the life span (Maher et al., 2013, 2014, 2015). Concerning the within-person association between objectively measured physical activity and life satisfaction, the null findings from this study differed from those of previous research (Maher et al., 2014). Maher and colleagues (2014) expressed physical activity as average hourly volume (activity counts/hour) whereas, in this study, physical activity was expressed as duration (time spent stepping/day). Volume is the product of intensity and duration. In this study, physical activity was void of any information about intensity of the physical activity. It may be that older adults need to engage in a certain intensity of physical activity to enhance well-being. Future research investigating within-person associations between objectively measured physical activity and life satisfaction in older adults should attempt to capture the volume of physical activity.

Across both models, findings from this study suggested that sedentary behavior and physical activity do not have additive associations with life satisfaction in older adults. This finding contrasts with studies that documented independent and additive associations with indicators of well-being (Balboa-Castillo et al., 2011; Hamer & Stamatakis, 2013; Hamer et al., 2013; Kesse-Guyot et al., 2012; Van Uffelen et al., 2013). However, the lack of independent associations may be due to differences in measurement previously outlined. Using objective measures of behavior that are not subject to the influences that can affect people's perceived time use (e.g., values, interests, and goals) may yield the strongest conclusions regarding these additive associations. Furthermore, results from this study suggest that objective measures of physical activity that capture volume or frequency, as opposed to duration, may be most appropriate for documenting associations between physical activity and life satisfaction in older adults.

Finally, results from this study strengthen our conclusions regarding the direction of the relationship between health behaviors and life satisfaction and are consistent with those from previous work investigating the directionality of these associations (Maher et al., 2013, 2014, 2015). Given these findings, it would suggest that interventions targeting small changes in daily life (e.g., taking the stairs instead of the elevator [to increase daily physical activity] or standing during the commercial breaks [to reduce sedentary behavior]) may have a greater impact on life satisfaction than more dramatic, sustained changes in behavior (i.e., adopting a new exercise program or removing all chairs from one's home). Furthermore, these small changes are likely to be more manageable and easier to incorporate into daily life. Interventions designed to enhance well-being in older adults should consider targeting daily changes in total sedentary behavior and daily changes in the volume or frequency of bouts of physical activity. Such an intervention might have older adults identify times during the day during which they sit for more than an hour at a time and then develop detailed plans (i.e., action plans) to break up that hour of sitting with a few minutes or standing or walking. This would allow older adults to displace sedentary time with physical activity in the hopes of enhancing life satisfaction. The plans would be developed daily and adapt to the demands of each day in the hope of reducing sedentary time or increasing physical activity relative to typical levels for each older adult.

Another implication of findings from this study is that sedentary behavior and physical activity can be targeted as an intervention on days that older adults struggle with life satisfaction and not targeted on other days. This would lead to more efficient deployment of interventions, conservation of the self-regulatory resources required to control health behaviors, reduced burden for older adults, and possibly more effective interventions.

Some limitations should be noted. First, our sample was homogeneous with respect to race and ethnicity. Additionally, we excluded participants with functional limitations that prevented them from standing or walking on their own. Future research is needed in populations of pre-frail and frail older adults because their sedentary behavior is problematic and may accelerate declines in health (Blodgett, Theou, Kirkland, Andreou, & Rockwood, 2015). Additionally, because of our inclusion criteria, it is unclear whether associations documented in this study are also true for older adults who sit for less than 8 hours/day (which represents less than a third of the older adult population; Harvey, Chastin, & Skelton, 2013; Harvey et al., 2015). Investigating these associations in more diverse samples will be critical in understanding how health behaviors can be used as a way to promote well-being and quality of life in a variety of aging populations.

Due to the intensive sampling design of this ecological momentary assessment study, we used a single-item measure of life satisfaction to reduce participant burden. Future research should examine within-person associations between health behaviors and life satisfaction using other measures of life satisfaction, which represent the broader content universe.

Furthermore, life satisfaction and self-reported health behaviors were assessed at the end of each day. End-of-day assessments may have impacted results due to fatigue or circadian processes (e.g., melatonin and cortisol). Moreover, problems inherent with recall may have obscured participants' self-reports of behavior. Therefore, it may be valuable to sample life satisfaction, as well as sedentary behavior, at different times throughout the day to further untangle the association between sedentary behavior and life satisfaction, while reducing recall burden.

The observational nature of this study precludes conclusions about causality. We tested and were able to rule out one plausible alternative causal sequence to strengthen confidence in our conclusions. We also controlled for several plausible time-varying and time-invariant third variables; however, a number of other plausible third variables were not controlled (e.g., perceived control, goal pursuits, positive and negative affect, health-related quality of life, social engagement, and loneliness). Experimental work is needed to determine the casual role that sedentary behavior and physical activity play in regulating life satisfaction.

In conclusion, this study elaborated on associations between sedentary behavior, physical activity, and life satisfaction in older adults. Associations differed between self-report and objective measures of behavior. Results from this study suggested that daily changes in sedentary behavior or physical activity, but not both, have implications for older adults' daily life satisfaction. Usual sedentary behavior and physical activity were not associated with older adults' daily life satisfaction. Interventions designed to enhance daily life satisfaction in older adults should emphasize daily changes in total sedentary behavior and daily changes in the volume or frequency of physical activity.

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