Daily physical activity and life satisfaction across adulthood

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Abstract:

Physical activity is considered a valuable tool for enhancing life satisfaction. However, the processes linking these constructs likely differ across the adult life span. In older adults the association between physical activity and life satisfaction appears to involve usual levels of physical activity (i.e., a between-person association driven by differences between more and less active people). In younger adults the association has consistently been based on day-to-day physical activity (i.e., a within-person association driven by differences between more and less active days). To resolve this inconsistency, a daily diary study was conducted with a life span sample of community-dwelling adults (age 18–89 years; N = 150) over three 21-day measurement bursts. Usual physical activity was positively associated with life satisfaction in middle and older adulthood; however, this association was not present in young adulthood. When present, this between-person association was mediated by physical and mental health. A within-person association between physical activity and life satisfaction was also present (and did not differ across age). Generally, on days when people were more physically active then was typical for them, they experienced greater life satisfaction. Age differences in life satisfaction followed a cubic trajectory: lower during emerging adulthood, higher during midlife, and lower during older adulthood. This study adds to accumulating evidence that daily fluctuations in physical activity have important implications for well-being regardless of age, and clarifies developmental differences in life satisfaction dynamics that can inform strategies for enhancing life satisfaction.

Keywords: development | exercise | well-being | intraindividual | life stages

Article:

Life satisfaction serves as an indicator of well-being and prosperity for individuals as well as nations (Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004). Given the far-reaching implications of well-being, strategies to enhance life satisfaction are needed. One lifestyle behavior that has been linked with life satisfaction is physical activity (e.g., Penedo & Dahn, 2005; Rejeski & Mihalko, 2001); however, findings regarding the processes underlying that association at different segments of the adult life span have been inconsistent. Specifically, research on older adults suggests that physical activity and life satisfaction are linked by fitness- and health-related differences between people, whereas research on emerging adults suggests that these constructs are linked by a within-person revitalization process. There has yet to be a simultaneous examination of the between- and within-person processes linking physical activity and life satisfaction across the adult life span. We sought to resolve some of the gaps in the literature by investigating these relations from a lifespan developmental perspective, and by examining potential mediators of this association and how those mediators may differ across the adult life span.

Life Satisfaction Across the Adult Life Span

Life satisfaction refers to a cognitive evaluation or judgment of one's life, and it is one of several important contributors to the broader construct of mental health (Diener, 1984; Murthy et al., 2001). Influences on life satisfaction are conceptualized as being either "top–down" or "bottom–up" (Diener, 1984). 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). Although these influences are well documented, top–down and bottom–up influences have yet to be incorporated into a developmental framework that simultaneously examines changes in life satisfaction over time and across the life span.

In this article, when discussing life satisfaction across the adult life span, we refer to four main developmental periods: (a) emerging adulthood (ages 18–25), (b) young adulthood (ages 26–34), (c) middle adulthood (used interchangeably with *midlife*; ages 35–64), and (d) older adulthood (ages 65+; Arnett, 2000; Levinson, 1986). Life satisfaction was once thought to remain relatively stable across the life span (Diener, 1996; Diener & Lucas, 1999; Diener, Lucas, & Scollon, 2006). A growing body of evidence, however, has revealed that life satisfaction changes. Several studies have documented a U-shaped trajectory in life satisfaction across the life span, with satisfaction reaching its lowest point between an adult's mid-30s and early 50s (e.g., Blanchflower & Oswald, 2008; López Ulloa, Møller, & Sousa-Poza, 2013; Stone, Schwartz, Broderick, & Deaton, 2010). For example, Blanchflower and Oswald (2008) examined life satisfaction in Eurobarometer data pooled from 1976 to 2002, that included over 500,000 adults from ages 20 to 85+, and found that life satisfaction reached its minimum in between ages 44 and 49. In contrast, other studies have documented relative stability across the life span until reaching the second half of the life span. Across several sets of national panel data, Frijters and Beatton (2012) found that for the first half of the adult life span satisfaction was moderately high and stable, but upon reaching the mid-50s life satisfaction began to increase slightly until the mid-60s and then began to decrease. Other studies have documented a curvilinear trajectory where satisfaction is lower during emerging and young adulthood, higher throughout middle adulthood, and then lower again during older adulthood (e.g., Baird, Lucas, & Donnellan,

2010; Gwozdz & Sousa-Poza, 2010). Baird et al. (2010) examined life satisfaction from age 16 to 91 in the British Panel Household Study. Results revealed that life satisfaction was moderately high across the life span, but decreased in emerging and young adulthood, reached its low point at approximately age 46, then increased throughout the rest of middle adulthood until reaching the transition to older adulthood when it began decreasing again. Regardless of the shape of the trajectory, several explanations could explain changes in life satisfaction across the life span. One explanation that emerges from lifespan developmental frameworks, and which is used as an illustrative example throughout this article, suggests that differences in life satisfaction stem from age-related changes in motives and goals (Baltes & Baltes, 1990; Carstensen, 2006; Heckhausen, Wrosch, & Schulz, 2010). The lifespan approach explicitly acknowledges that people select and pursue different goals depending on the opportunities and constraints that accompany different developmental periods (Marsiske, Lang, Baltes, & Baltes, 1995). Life satisfaction is derived from goal attainment.

For example, as people age, their normative physiological and psychological capabilities decline. These declines create new barriers for midlife and older adults' goal pursuits, threaten their sense of self, and thus contribute to declines in life satisfaction (Gerstorf et al., 2010; Gwozdz & Sousa-Poza, 2010; Kunzmann, Little, & Smith, 2000; Smith, Borchelt, Maier, & Jopp, 2002). Because emerging adults do not typically experience the effects of aging that midlife and older adults do, their life satisfaction is not coupled with such slow changes in health.

There are also within-person mechanisms that are likely associated with life satisfaction uniformly regardless of position in the adult life span. Throughout adulthood, developmentally appropriate goals are prioritized and resources are mobilized in pursuit of those personally relevant goals. However self-regulatory resources have a limited capacity and the depletion of these resources is taxing (Baumeister, Bratslavsky, Muraven, & Tice, 1998). Physical activity has a revitalizing effect that may restore self-control and support goal pursuits. Inadequate resources can thwart goal pursuits and, thus, detract from life satisfaction throughout adulthood. In complement, adequate self-regulatory resources can facilitate goal pursuit and attainment, and thus contribute to life satisfaction throughout adulthood.

The usual and daily processes by which life satisfaction is attained are likely to differ across the adult life span. For example, the motivational theory of lifespan development posits that people's goals and motives change across the life span as a result of changes in social, family, and occupational roles, physical functioning, and behavior (Heckhausen et al., 2010). One behavior that may be particularly influential on the dynamics of goal pursuits and life satisfaction is physical activity. As we detail below, usual physical activity is likely associated with life satisfaction through fitness- and health-related (between-person) processes whereas daily physical activity is likely associated with life satisfaction through revitalization (within-person) processes.

The Association Between Health-Related Processes and Life Satisfaction

Regular physical activity, through fitness and health adaptations, is among the tools used to delay the onset and slow the progression of functional declines that occur during later life (Keysor, 2003; Miller, Rejeski, Reboussin, Ten Have, & Ettinger, 2000; Paterson & Warburton,

2010; Physical Activity Guidelines Advisory Committee, 2008). Maintenance of health and fitness can allow midlife and older adults to pursue relevant goals, feel competent, and maintain a sense of identity—all in turn contributing to life satisfaction (e.g., Berg, Hassing, McClearn, & Johansson, 2006; Borg, Hallberg, & Blomqvist, 2006). In contrast, for emerging and young adults, life satisfaction may not depend on the health benefits of usual physical activity because they typically are not experiencing age-related declines in health that would threaten their ability to attain important goals.

Usual Physical Activity

Cross-sectional and prospective studies examining the association between physical activity and life satisfaction in midlife and older adults find that more active people generally tend to experience greater life satisfaction compared with less active peers (Courneya & Friedenreich, 1997, 1998; Elavsky & McAuley, 2005; Elavsky et al., 2005). These studies of older adults suggest the working hypothesis that adults who engage in more usual physical activity will report greater life satisfaction than those who engage in less usual physical activity. However, studies with samples of emerging adults have failed to support that hypothesis (Maher et al., 2013; Maher, Doerksen, Elavsky, & Conroy, 2014). Among emerging adults, usual levels of physical activity appear to be unrelated to life satisfaction. The association between usual physical activity and life satisfaction appears to differ depending on life stage.

Potential Mediating Variables

Usual physical activity is a well-established predictor of both global physical and mental health as well as specific aspects of physical and mental health (Physical Activity Guidelines Advisory Committee, 2008). Additionally, aspects of usual physical and mental health have been shown to contribute to life satisfaction (e.g., presence of disease and chronic conditions, usual health status, usual self-efficacy, usual self-esteem, usual positive affect; Elavsky et al., 2005; Gana et al., 2013). In our analyses we controlled for both physical and mental health to strengthen confidence in conclusions about the between-person association between physical activity and life satisfaction.

The Association Between Revitalization Processes and Life Satisfaction

Both physical activity and life satisfaction change from day to day (Conroy, Elavsky, Hyde, & Doerksen, 2011; Heller, Watson, & Ilies, 2006; Maher et al., 2013, 2014). Accumulating physical activity within a day revitalizes people by increasing feelings of energy, reducing feelings of fatigue, and enhancing pleasant affect (Puetz, O'Connor, & Dishman, 2006; Reed & Ones, 2006). This revitalizing effect of daily physical activity may be responsible for people reporting greater life satisfaction on days they are more active than usual (i.e., within-person association).

Daily Physical Activity

In two separate samples of emerging adults, Maher et al. (2013) found that emerging adults reported higher life satisfaction on days when they participated in more physical activity than

was typical for them (i.e., a within-person association), a pattern that replicated when using direct measures of physical activity (i.e., accelerometer; Maher et al., 2014). Although this association has not been examined at later stages of adulthood, it seems likely that the within-person process that links daily changes in life satisfaction with physical activity applies across all of adulthood because the revitalizing effect of acute physical activity serves to invigorate goal pursuit and life satisfaction, regardless of age (Puetz et al., 2006).

Potential Mediating Variables

A variety of daily events and experiences may be linked with both physical activity and life satisfaction. For example, day-to-day changes in both physical and mental health (e.g., cold symptoms, minor injuries, depression, hangovers) have previously been associated with life satisfaction in samples of emerging adults (Maher et al., 2014). These daily health concerns can also serve as barriers to physical activity (Bauman, Sallis, Dzewaltowski, & Owen, 2002; Sherwood & Jeffery, 2000). To strengthen confidence in conclusions about the within-person association between physical activity and life satisfaction, we controlled daily physical and mental health in our analyses.

Potential Confounding Variables

Potentially confounding variables on relations between physical activity and life satisfaction involve environmental factors (e.g., weather), the social calendar, and reactivity to research procedures. Seasonal changes in the amount of daylight (i.e., photoperiod) can have affective consequences (Wehr & Rosenthal, 1989; Young, Meaden, Fogg, Cherin, & Eastman, 1997). Physical activity also varies as a function of weather (which varies seasonally; Tucker & Gilliland, 2007). Similarly, the social calendar is relevant because of systematic day-of-week differences in both well-being and physical activity (Conroy, Elavsky, Doerksen, & Maher, 2013; Stone, Schneider, & Harter, 2012). Finally, it is possible for reactivity to repeated assessments to impact behavior and evaluations (Shiffman, Stone, & Hufford, 2008). To control for these factors, we included seasonal position, a set of dummy variables representing the day-of-week, and time-in-study as additional predictors of daily life satisfaction. All hypothesized associations between physical activity and life satisfaction were expected to be robust after controlling for these potential confounds.

THE PRESENT STUDY

Prior findings in midlife and older adults are consistent with the idea that usual levels of physical activity are associated with life satisfaction through fitness- and health-related adaptations that enhance physical and mental health; however, in samples of emerging and young adults, usual levels of physical activity have been unrelated to life satisfaction. Prior findings with emerging and young adults are consistent with the idea that physical activity is associated with life satisfaction through acute revitalization processes. Although the association between daily physical activity and life satisfaction has yet to be evaluated in midlife or older adults, daily physical activity is likely associated with life satisfaction at any age because physical activity's acute revitalization effect has been documented across the adult life span. Additionally, recent evidence suggests that life satisfaction may be lower during emerging and older adulthood due to

challenges and declines faced during these developmental periods, respectively (Arnett, 2000; Birren & Cunningham, 1985; Gerstorf et al., 2010; Gerstorf, Ram, Röcke, Lindenberger, & Smith, 2008). Furthermore, during middle adulthood life satisfaction may be higher due to a shifting focus from others (e.g., children) to the self, as well as career development (Lachman, 2004). Thus, we hypothesized that (a) daily physical activity would be positively associated with daily life satisfaction across the adult life span (within-person association); (b) usual physical activity and life satisfaction would be positively associated among older but not younger adults (between-person association); (c) the association between usual physical activity and life satisfaction would be mediated by the beneficial effects of physical activity on physical and mental health; and (d) levels of life satisfaction would differ across the adult life span, with emerging and older adults experiencing lower levels of life satisfaction and midlife adults experiencing higher levels of life satisfaction. To test these hypotheses, we analyzed data from a daily diary study with a sample spanning the full range of adulthood (age 18–89).

A daily diary study provides an optimal sampling period for investigating life satisfaction dynamics because the assessment cadence coincides with light–dark and sleep–wake cycles that impact well-being. Moreover, the changing context of people's daily lives is associated with changes in their motivation, behavior, and well-being (Conroy et al., 2013). In this study, sufficient daily assessments were obtained through the use of a multiple time-scale study design (Nesselroade, 1991; Ram & Gerstorf, 2009; Sliwinski, 2008), wherein daily reports were distributed across three 21-day periods. The robust sampling across a year of individuals' daily lives allows for the separation and simultaneous evaluation of within- and between-person associations between physical activity and life satisfaction, through fitness- and health-related adaptations as well as daily revitalization, and provides an opportunity to account for other (e.g., contextual) processes unfolding at different time scales (e.g., age, seasonal changes, social calendar) that may impact behavior, evaluative processes, or both.

METHOD

Participants

Data for this study were drawn from the Intraindividual Study of Affect, Health and Interpersonal Behavior (iSAHIB; Ram et al., 2014), an intensive multiple time-scale longitudinal study of 150 (51% women) community-dwelling adults age 18 to 89 years (at study start M = 47.51, SD = 18.64). Participants were purposefully stratified by age and gender to ensure a roughly equal number of men and women in five age groups: 18 to 24 (n = 22), 25 to 34 (n = 27), 35 to 49 (n = 30), 50 to 64 (n = 41), 65+ (n = 30). The majority of participants were Caucasian (91%; 4% African American; 1% Asian American; 2% mixed; 2% other) and of heterosexual orientation (93%). At the start of the study, approximately 49% of the sample was employed full-time, 30% were employed part-time or were students, 18% were retired, and 3% were not employed. Thirty-six percent of participants reported earning less than $49,999 annually, another 36% of participants reported earning between $50,000 and $99,999 annually, and the remaining participants reported earning more than $100,000 annually (8% of the sample declined to answer). On average, participants had obtained slightly over 16 years of schooling (M = 16.36, SD = 3.90). Most of the sample (67%) reported being married or in a committed

relationship, with the rest of the sample being single (15%); divorced, separated, or widowed (14%); or in a casual relationship (4%).

Procedure

Over a period of about one year, participants completed a series of web- and smartphone-based questionnaires during visits to the laboratory and as they went about their daily lives. Participants were asked to complete three 21-day "measurement bursts," for a total of 63 days of data per participant. Upon completion of a burst, participants took a hiatus from daily data collection before beginning the next burst of data collection. Intervals between bursts varied, with an average interval between Bursts 1 and 2 of 4.5 months (*SD* = 1.1; range = 1.7–8.2 months) and an average interval between Bursts 2 and 3 of 3.5 months (*SD* = 1.2; range = 0.0–6.2 months). On average, participants completed the entire protocol over 10.2 months (*SD* = 1.8; range = 3.9–13.2 months).

At the beginning of each burst, participants attended a brief introductory session where they provided consent, were familiarized with the study procedures, were taught how to operate the smartphone that would be used to complete the temporally intensive surveys, and completed a baseline assessment (e.g., demographic information, changes in health, job, relationship status). Over the next 3 weeks, participants provided event-contingent reports about their interpersonal behavior throughout the day, and completed a brief end-of-day survey where they answered questions about the behaviors, thoughts and feelings they had that day. Upon completion of each survey, data were encrypted and transmitted to a secure server for real-time compliance checks and later analysis. At the conclusion of each burst, participants returned to the lab to return the smartphone and complete a brief questionnaire and end-of-burst interview. All study procedures were approved by the local institutional review board.

Over the course of the study, a total of 14 individuals discontinued participation. Ten participants dropped out between Bursts 1 and 2 (resulting *n* = 140) and four participants dropped out between Bursts 2 and 3 (resulting *n* = 136). Reasons for attrition were participants moving out of the area (*n* = 10), research team initiated discontinuation due to noncompliance with the research protocol (*n* = 3), and health problems (*n* = 1).

In total, participants provided data for a total of 8,574 of the possible 8,946 person-days (95.8% response rate), with two thirds of the sample providing data for at least 59 of the 63 days (Median # of days = 61, *M*# of days = 56.10, *SD*# of days = 12.94, range = 13–76). Missing data on the specific variables of interest here (<1%, n*observations* = 33) were treated as missing completely at random. The final sample consisted of 8,541 daily self-reports from 150 persons.

Measures

Measures used in the present analysis were drawn from the end-of-day surveys (obtained during all three bursts unless otherwise specified) and initial demographic questionnaire.

Life satisfaction

Daily life satisfaction was assessed using a single item from the Satisfaction With Life Scale (SWLS; 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 was digitally coded on a 0 (*strongly disagree*) to 100 (*strongly agree*) scale. A single item was used to reduce participant burden, with the specific item selected through factor analysis (highest loading item) of complete five-item SWLS data from an 8-day daily diary study (see Maher et al., 2013).

Physical activity

Daily physical activity was measured using a modified version of the Godin Leisure Time Exercise Questionnaire (Godin, Jobin, & Bouillon, 1986; Godin & Shephard, 1985). The LTEQ is a validated measure of adult physical activity (Jacobs, Ainsworth, Hartman, & Leon, 1993). Although traditionally administered as a previous-week recall measure, the measure was modified to assess daily physical activity, and thus reducing potential recall bias and reliance on personal heuristics to estimate physical activity (Matthews, Moore, George, Sampson, & Bowles, 2012; Schwarz, 2007). Participants were instructed to indicate how many times they engaged in (a) strenuous (e.g., running, vigorous swimming), (b) moderate (e.g., fast walking, volleyball), and (c) mild exercise (e.g., easy walking, yoga) for at least 10 min throughout their free time during the day. To alleviate potential confusion about how their activities fit within this taxonomy, participants were encouraged to make use of a "help" button that appeared along with the item and provided definitions of each intensity level and examples of qualifying activities. Using the LTEQ scoring procedure, responses were weighted by standard metabolic equivalents (MET; *vigorous physical activity*= 9, *moderate* = 5, *mild* = 3) and summed to create a daily MET or energy expenditure score. Higher scores were indicative of greater physical activity energy expenditure.

Physical and mental health

Daily physical and mental health status was assessed using two items from the Health-Related Quality of Life Questionnaire (Hennessy, Moriarty, Zack, Scherr, & Brackbill, 1994). These items were modified to reflect daily status as opposed to symptoms over the past 30 days. Specifically, daily physical and mental health status were assessed using the items, "Today, my physical health was . . ." and "Today, my mental health was . . .," each rated on a digitally coded slider with anchors at 0 (*not good*) and 100 (*very good*). Daily physical and mental health status were obtained during Bursts 2 and 3 of data collection.

Temporal processes

Temporal processes were coded on three time scales. First, to account for the seasonal effect, we estimated the *length of day* based on the amount of sunlight during each day of the study. To do this, we created a variable based on the dates that the summer and winter solstices fell between 2009 and 2011. A cosine function was used to represent the amount of sunlight for each day. A value of 1 represents the day with the most sunlight (i.e., summer solstice) and a value of −1 represents the day with the least sunlight (i.e., winter solstice). Second, to control for the possibility that life satisfaction changed as a result of, or was reactive to, participating in the

study we created two within-person variables to represent *exposure to questionnaires*. These exposure variables accounted for (a) the burst in the study (1, 2, or 3) and (b) the day in the burst (1 to 21). Third, we created six dummy variables representing the days of the week to account for possible effects of the *social calendar*. Tuesday served as the reference category because sample-level average life satisfaction was lowest on this day of the week.

Demographics

At the initial lab visit prior to beginning Burst 1, participants provided demographic information regarding their sex, age, ethnicity, sexual orientation, education level, employment and marital status, and income.

Data Analysis

Multilevel models (e.g., Snijders & Bosker, 1999) were used to examine associations between physical activity and life satisfaction at the between-person 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. Following standard multilevel modeling practice, pseudo-R^2, the additional proportion of variance explained by the predictors compared with a baseline model, was computed as an effect size (Snijders & Bosker, 1999).

Data preparation

At the sample level, the distribution of physical activity scores was significantly skewed ($p < .05$). Thus, the Box–Cox method (Box & Cox, 1964; Osborne, 2010) was used to normalize the distribution through optimal power-law transformation. All reported correlations and parameter estimates for physical activity were calculated using transformed values. Daily ratings of predictor variables (e.g., physical activity) were aggregated and person-centered to separate and simultaneously test between- and within-person associations (see Bolger & Laurenceau, 2013). For example, person *i*'s usual physical activity (*Usual PAi*) was calculated as the within-person mean of her daily self-reported physical activity across days, and daily physical activity (*Daily PAdi*) was calculated as the deviation of day *d*'s score from her usual physical activity (i.e., cluster-mean centering; Enders & Tofighi, 2007). As such, the within-person mean scores across the 63 days differentiate between more or less active *people*, and, daily deviations differentiate more or less active *days*. Usual and daily mental and physical health status scores were calculated in the same way. Age and exposure to study variables were also group-mean and cluster-mean centered, respectively.

Multilevel models

Multilevel models were used to accomplish the objectives outlined previously. Specifically, life satisfaction on day *d* for person *i*, *LSdi*, was modeled (Model 1) as

$$LS_{di} = \beta_{0i} + \beta_{1i}(\text{Daily PA}_{di}) + \beta_{2i}(\text{Monday}_{di}) + \beta_{3i}(\text{Wednesday}_{di}) + \beta_{4i}(\text{Thursday}_{di}) + \beta_{5i}(\text{Friday}_{di}) + \beta_{6i}(\text{Saturday}_{di}) + \beta_{7i}(\text{Sunday}_{di}) + \beta_{8i}(\text{StudyBurst}_{di}) + \beta_{9i}(\text{StudyDay}_{di}) + \beta_{10i}(\text{DayLength}_{di}) + e_{di} \quad (1)$$

with

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(\text{Usual PA}_i) + \gamma_{02}(\text{Age}_i) + \gamma_{03}(\text{Age}_i^2) + \gamma_{04}(\text{Age}_i^3) + \gamma_{05}(\text{Usual PA}_i \times \text{Age}_i) + u_{0i} \quad (2)$$

$$\beta_{1i} = \gamma_{10} + \gamma_{11}(\text{Usual PA}_i) + \gamma_{12}(\text{Age}_i) + u_{1i} \quad (3)$$

$$\beta_{(2-10)i} = \gamma_{(2-10)0} \quad (4)$$

where γ00 is the expected level of life satisfaction for the average person in the sample on a typical Tuesday, γ01 indicates the between-person associations between usual physical activity and life satisfaction, γ02 − γ04 capture the linear, quadratic, and cubic relations between age and life satisfaction, and γ05 indicates the extent to which age moderates the associations between physical activity and daily life satisfaction (*LSdi*). In turn, γ10 indicates the strength of the within-person association between daily physical activity and life satisfaction for the average person, γ11 and γ12 indicate the extent to which the within-person association is moderated by usual physical activity and age, respectively. Controls for day of week, burst, day in study, and length of day are captured by γ20 to γ100. Unexplained between-person differences in typical level of life satisfaction and the within-person association between daily physical activity and life satisfaction are captured by *u0i* and *u1i*, which may correlate with each other, but are uncorrelated with unexplained day-to-day differences in life satisfaction, *edi*.

Building from this model, a second set of multilevel models were used to investigate the possible mediating role of physical and mental health in the between- and within-person associations of physical activity and life satisfaction. These models relied on a subset of data (i.e., data from Burst 2 and 3) because the daily physical and mental health assessments were added at Burst 2. The multilevel mediation analyses followed standard procedures outlined by Krull and MacKinnon (2001). To examine the mediating influence of usual physical and mental health (Level-2, between-person variables) in the association between usual physical activity (Level-2 variable) and daily life satisfaction (Level-1, within-person variable), 2–2–1 multilevel mediation models were estimated. To examine the mediating influence of daily physical and mental health (Level-1 variables) in the association between daily physical activity (Level-1 variable) and daily life satisfaction (Level-1 variable), 1–1–1 multilevel mediation models were estimated. Figure 1 displays examples of these multilevel mediation models. These multilevel models provide for estimation of the indirect or mediated effect of a single mediator (operationalized as *ab*) as well as the total mediation effect (operationalized as *c-c'*, where c refers to the path from X to Y when M is absent) while accounting for repeated assessments within people (Bauer, Preacher, & Gil, 2006).

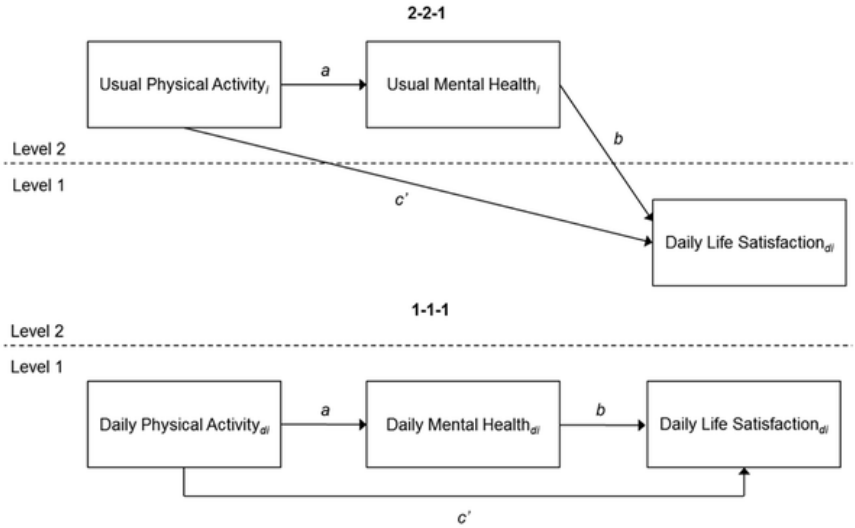

Figure 1. An illustrative example of a 2–2–1 (top panel) and 1–1–1 (bottom panel) multilevel mediation models adapted from Zhang, Zyphur, and Preacher (2009).

In follow-up analyses we also (a) examined how robust the pattern of associations was to reversal of the temporal sequencing (life satisfaction as a predictor of next-day physical activity) and (b) included other time-invariant covariates, including sex, ethnicity, income, body mass index, Big 5 personality characteristics, and functional limitations, role limitations due to physical health, pain, and general health (from the Short Form [36] Health Survey; Ware, Kosinski, Dewey, & Gandek, 2000) in our multilevel models. The additional covariates did not change the pattern of results, so the more parsimonious models are presented throughout.

RESULTS

Descriptive statistics, including the between- and (average) within-person correlations among life satisfaction, physical activity, health, and age are shown in Table 1. On average participants reported moderate-to-high levels of daily life satisfaction (M = 70.16 on a 0 to 100 scale). Additionally, participants' average level of daily physical activity was equivalent to engaging in slightly more than two bouts of moderate-intensity physical activity each day. Participants' self-reported daily physical and mental health also appeared to be moderately high (M = 64.98 and 70.49, respectively, on a 0 to 100 scale). Correlations at the between- and within-person level exhibited similar patterns. Life satisfaction had weak positive correlations with physical activity (rs = .14, .18) and strong correlations with physical health (rs = .59, .76) and mental health (rs = .73, .85). Life satisfaction was not correlated (linearly) with age (rs = −.01). The intraclass correlation coefficients shown along the diagonal of the matrix in Table 1 indicated that approximately half of the variance in daily life satisfaction, physical health, and mental health, and one third of the variance in daily physical activity was between-person variance, with the remainder driven by within-person factors (and measurement error).

Table 1
Descriptive Statistics, Correlations, and Intraclass Correlations of Life Satisfaction and Predictor Variables

Variable	*M*	*SD*	1	2	3	4
1. Life satisfaction	70.16	19.75	(.57)	.18	.76	.85
2. Physical activity	11.46	12.46	.14	(.33)	.21	.14
3. Physical health	64.98	21.64	.59	.18	(.63)	.70
4. Mental health	70.49	21.10	.73	.10	.56	(.63)
5. Age	47.51	18.64	−.01	−.02	−.04	.10

Note. Life satisfaction, physical activity, and age data are based on up to 63 daily reports nested within 150 participants for a total of 8,562 observations. Physical and mental health data are based on up to 42 daily reports nested within 140 participants for a total of 5,694 observations. Intraclass correlation coefficients representing the proportion of between-person variance appear in parentheses on the diagonal of the correlation matrix. Coefficients below the diagonal are correlations across days and people. Coefficients above the diagonal represent correlations of within-person means. Means and standard deviations were calculated using raw data. Correlations were calculated using transformed scores. *M* = sample-level mean, *SD* = sample-level standard deviation.

Life Satisfaction Across Adulthood

Table 2 presents parameter estimates and standard errors from Model 1 (based on up to 63 days of data nested within 150 persons = 8,562 observations) examining the between- and within-person associations between physical activity and life satisfaction and the extent to which age moderated those associations, controlling for temporal changes/cycles. We found statistically significant linear ($\gamma 02 = 0.28$, $p < .05$), quadratic ($\gamma 03 = 0.01$, $p < .05$), and cubic ($\gamma 04 = 0.01$, $p < .05$) associations between age and life satisfaction. The resulting curvilinear trajectory of age-related differences in life satisfaction is shown in Figure 2. Life satisfaction decreased across emerging and young adulthood (ages 18–35 years), held steady or increased during middle adulthood (ages 36–68 years), then steadily decreased again during older adulthood (ages 69–89 years).

Table 2
Results From Multilevel Model Examining Between-Person and Within-Person Associations of Physical Activity With Daily Life Satisfaction

Variable	Parameter estimate	*SE*
Fixed effects		
Intercept, γ_{00}	66.30*	1.77
Usual physical activity, γ_{01}	2.34*	0.91
Daily physical activity, γ_{10}	0.91*	0.14
Usual Physical Activity × Daily Physical Activity, γ_{11}	0.00	0.11
Age, γ_{02}	0.28*	0.14
Age^2, γ_{03}	0.01*	0.00
Age^3, γ_{04}	0.01*	0.00
Age × Usual Physical Activity, γ_{05}	0.12*	0.05
Age × Daily Physical Activity, γ_{12}	−0.01	0.01
Monday, γ_{20}	0.43	0.51
Wednesday, γ_{30}	0.02	0.51
Thursday, γ_{40}	0.90	0.51
Friday, γ_{50}	1.55*	0.52
Saturday, γ_{60}	2.28*	0.52
Sunday, γ_{70}	1.64*	0.52
Day count, γ_{80}	1.81	1.38
Day length, γ_{90}	0.32	6.67
Burst, γ_{100}	6.33	6.03
Random effects		
Intercept, σ^2_{u0i}	198.79*	24.09
Daily physical activity, σ^2_{u1i}	1.72*	0.36
Covariance, $\sigma_{u0i,u1i}$	−6.31*	2.16
Residual, σ^2_{edi}	160.35*	2.50
−2LL	68,535.9	
AIC	68,543.9	

Note. Unstandardized estimates and standard errors. Model is based on up to 63 daily reports nested within 150 participants for a total of 8,562 observations. An additional multilevel model was tested that included time-invariant covariates (sex, ethnicity, income, body mass index, Big Five personality characteristics, and functional limitations, role limitations due to physical health, pain, and general health [from the SF36]); however, adding these covariates did not change the findings from this analysis so we present the more parsimonious model. −2LL = −2 log likelihood; AIC = Akaike information criterion.
* $p < .05$.

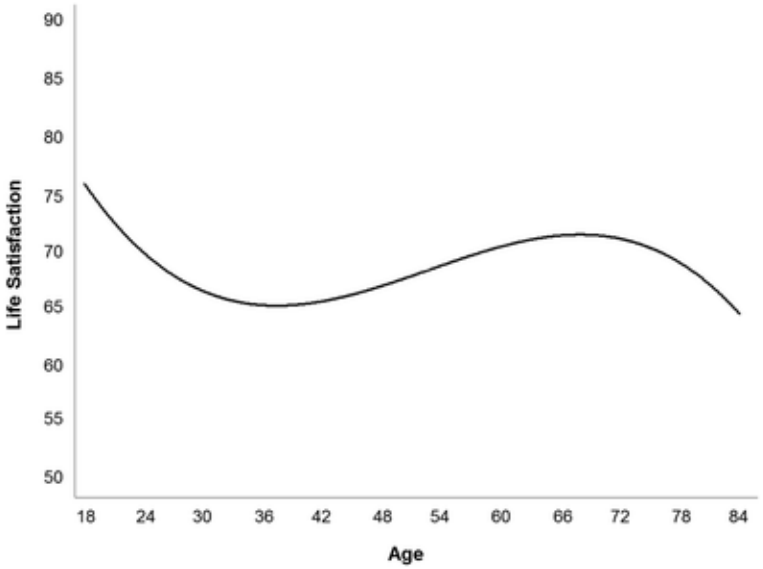

Figure 2. Age-related differences in ratings of life satisfaction. Cubic trajectory based on parameter estimates of Model 1.

Associations Between Physical Activity and Life Satisfaction Across Adulthood

Higher levels of physical activity were associated with higher levels of life satisfaction, both between- and within-persons ($\gamma 01 = 2.34$, $p < .05$ and $\gamma 10 = 0.91$, $p < .05$, respectively). That is, people who engaged in more usual physical activity had higher life satisfaction (i.e., between-person association), and on days when the average person was more physically active than was typical for them (i.e., within-person association), they reported higher levels of life satisfaction. The between-person association between usual physical activity and life satisfaction was moderated by age ($\gamma 05 = 0.12$, $p < .05$), whereas the within-person association between daily physical activity and life satisfaction was not ($\gamma 12 = -0.01$, $p = .97$). Figure 3 depicts how age moderated the between-person association between usual physical activity and life satisfaction. This association was weak for young adults (– 1 *SD* age = 29 years), and became stronger and more positive across middle adulthood (age = 47 years) and into older adulthood (+1 *SD* = 65 years). Probing the interaction using the Johnson–Neyman method (implemented according to Preacher, Curran, & Bauer, 2006), we found that usual physical activity was unrelated to life satisfaction in young adulthood ($b = 0.23$, $SE = 0.19$, when age was <0.58 *SD*, i.e., < 37 years), but became significantly positive for individuals during midlife and older adulthood ($b = 0.67$, $SE = 0.17$, when age >0.58 *SD*, > 37 years]). Temporally, life satisfaction was significantly higher on Fridays ($\gamma 50 = 1.55$, $p < .05$), Saturdays ($\gamma 60 = 2.28$, $p < .05$), and Sundays ($\gamma 70 = 1.64$, $p < .05$) compared with Tuesdays (the reference day), but not related to burst in study ($\gamma 80 = 1.81$, $p = .19$, day in burst ($\gamma 90 = 0.32$, $p = .96$), or the length of day, ($\gamma 100 = 6.33$, $p = .29$). As indicated by the pseudo-R^2, Model 1 accounted for approximately 14% of the variance in daily life satisfaction, with daily physical activity accounting for 59% and usual physical activity accounting for 9% of the explained variance.

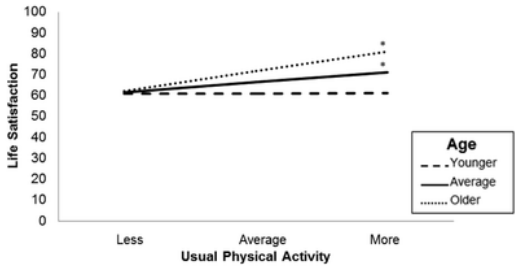

*Figure 3. Relations between life satisfaction and usual physical activity for younger (−1 SD age = 29 years), average (age = 47 years), and older (+1 SD age = 65 years) individuals, as evaluated at less (−1 SD physical activity = −1.00), average (physical activity = 11.46), and more (+1 SD physical activity = 23.92) levels of usual physical activity. Lines roughly correspond to young adulthood, middle adulthood, older adulthood, groups. * p < .05.*

This model was constructed on the assumption that the day's physical activity would influence end-of-day life satisfaction (as obtained by our assessment protocol). However, it is also possible that a given day's physical activity may have been influenced by the previous evening's life satisfaction. This alternative temporal sequence (i.e., previous day's life satisfaction influencing current day's physical activity) was tested in a follow-up analysis where daily physical activity was regressed on previous-day life satisfaction. In this set-up the associations between physical activity and life satisfaction were not significant at either the between- or within-person levels ($\gamma 01 = 0.07$, $p = .42$; $\gamma 10 = -0.01$, $p = .58$). Thus, we concluded that the between- and within-person associations between physical activity and life satisfaction reflect the influence of behavior on self-evaluation rather than the influence of self-evaluation on behavior.

Physical and Mental Health as Potential Mediators

To examine the mediating influence of usual physical and mental health in the between-person association between daily physical activity and life satisfaction, we used two 2–2–1 multilevel mediation models, applying them to a subset of the data because physical and mental health were only assessed during Burst 2 and 3 (up to 42 daily reports nested within 140 participants = 5,694 observations). In the test of physical health as a mediator, usual physical activity (X) was a significant predictor of usual physical health (M; $b = 2.02$, $SE = 0.14$, $p < .001$) and usual physical health (M) was also a significant predictor of daily life satisfaction (Y; $b = 0.66$, $SE = 0.05$, $p < .001$). There was no direct association between usual physical activity (X) and daily life satisfaction (Y) after adjusting for usual physical health (M; $b = 0.25$, $SE = 0.65$, $p = .69$), evidence of mediation. In the test of usual mental health as a mediator, usual physical activity (X) significantly predicted usual mental health (M; $b = 3.13$, $SE = 0.14$, $p < .001$) and usual mental health (M) was a significant predictor of daily life satisfaction (Y; ($b = 0.75$, $SE = 0.04$, $p < .001$). Again, there was no remaining association between usual physical activity (X) and daily life satisfaction (Y) after adjusting for usual mental health (M; $b = 0.65$, $SE = 0.51$, $p = .20$), evidence of mediation.

To examine the mediating influence of daily physical and mental health in the within-person association between daily physical activity and life satisfaction we used two 1–1–1 multilevel mediation models. In the test of daily physical health as a mediator, daily physical activity (X) significantly predicted daily physical health (M; $b = 1.15$, $SE = 0.17$, $p < .001$). Daily physical health (M) was also a significant predictor of daily life satisfaction (Y; $b = 0.22$, $SE = 0.02$, $p < .001$). There was still evidence of a direct effect of daily physical activity (X) on life satisfaction (Y) after adjusting for daily physical health (M; $b = 0.36$, $SE = 0.13$, $p < .01$). The total effect of daily physical activity on daily life satisfaction was calculated as 0.68 with 47% of the total

effect accounted for by daily physical health, partial mediation at best. In the test of daily mental health as a mediator, daily physical activity (X) significantly predicted daily mental health (M; $b = 0.56$, $SE = 0.13$, $p < .001$) and daily mental health (M) was a significant predictor of daily life satisfaction (Y; $b = 0.35$, $SE = 0.02$, $p < .001$). Again, there was still evidence of a direct effect of daily physical activity (X) on life satisfaction (Y) after adjusting for daily mental health (M; $b = 0.42$, $SE = 0.11$, $p < .001$). The total effect of daily physical activity on daily life satisfaction was calculated to be 0.67 with only 36% of the total effect accounted for by daily mental health, again partial mediation at best.

DISCUSSION

This study used a lifespan developmental perspective to address inconsistencies in the literature regarding the association between physical activity and life satisfaction across adulthood. Between-person, there was a significant association between usual physical activity and life satisfaction. This association was moderated by age and mediated by usual physical and mental health. Within-persons, there was, on average, a significant association between daily physical activity and life satisfaction. This association did not differ as a function of age and was not mediated by daily physical and mental health. We found that age differences in life satisfaction followed a cubic trajectory: lower during emerging adulthood, higher during midlife, and lower again during older adulthood.

The Association Between Health-Related Processes and Life Satisfaction

To the best of our knowledge, this study was the first to examine age-related differences in associations between physical activity and life satisfaction across adulthood. Results replicated previous findings of both a positive between-person association between usual physical activity and life satisfaction in midlife and older adults (Courneya & Friedenreich, 1997, 1998; Elavsky et al., 2005; e.g., Elavsky & McAuley, 2005; McAuley et al., 2008), and a null association in emerging adults (e.g., Maher et al., 2013, 2014). The change in association across adulthood was consistent with the motivational theory of lifespan development (Heckhausen et al., 2010). As individuals progress through the adult life span, maintaining health and functional independence become increasingly important goals (e.g., Callahan, 1992). Both physical and mental health play a key role in successful aging and optimizing well-being (Gerstorf et al., 2010) yet both of these factors have been suggested to decline with age (e.g., Blazer, 2003; Jernigan et al., 2001; Shephard, 1997). Decreases in health compromise goal attainment and consequently lower life satisfaction.

Previous research indicates that physical and mental health mediate the association between usual physical activity and life satisfaction in older adults (McAuley et al., 2006; Stewart & King, 1991). We can now elaborate that participating in regular physical activity contributes to greater life satisfaction in midlife and older adults because of its health impacts whereas emerging and young adults' life satisfaction is not affected by participating in regular physical activity because their health and functional independence have yet to be compromised by age-related decline. The present study provides the first evidence that physical and mental health become important mediators of this association in middle and older adulthood.

This study revealed no association, at the between-person level, between physical activity and life satisfaction in emerging or young adults; however, unmeasured mediators, such as body image or other appearance-related factors, could account for a link between physical activity and life satisfaction in these developmental periods and should be investigated in future research (Campbell & Hausenblas, 2009; Zullig, Pun, & Huebner, 2007).

The Association Between Revitalization Processes and Life Satisfaction

This study provided the first evidence of an age-invariant within-person association between physical activity and life satisfaction across the adult life span. Maher and colleagues (2013, 2014) previously explored this within-person association in three different samples of emerging adults, using both self-report and direct measures of physical activity. In those studies, the within-person association was robust even after controlling for a variety of potential confounding variables (e.g., personality, sex, self-esteem, physical and mental health, sedentary behavior, body mass index). Given that the revitalizing effect of physical activity can facilitate goal pursuit at all ages, the within-person association between daily physical activity and life satisfaction should be similar across the adult life span (Puetz et al., 2006). These findings may be especially promising for older adults who, for numerous reasons, lead fairly inactive lifestyles and may have difficulty meeting national physical activity guidelines (Troiano et al., 2008). Life satisfaction and positive affect increase in conjunction with a person engaging in more physical activity than is usual for them, so any increases in manageable lifestyle activities such as walking may be valuable for enhancing daily well-being even if the person cannot attain recommended levels according to national guidelines (Buman et al., 2010). Therefore, across the adult life span, adults should be able to improve their life satisfaction without needing to adopt dramatic lifestyle changes.

Finally, results from this study add to accumulating evidence that daily physical activity has a direct association with life satisfaction. Even after accounting for daily physical and mental health, two well-established mediators of the association between physical activity and life satisfaction, the within person-association between daily physical activity and life satisfaction remained. Further work is needed to explore other potential mediators to confirm that daily physical activity has a direct effect on life satisfaction. Acute bouts of physical activity can increase feelings of pleasant affect as well as self-perceptions including self-esteem, self-efficacy, and perceived behavioral control (e.g., Ekkekakis & Petruzzello, 1999; Hyde, Conroy, Pincus, & Ram, 2011; McAuley, Courneya, & Lettunich, 1991) and it may be that these acute benefits of physical activity are the mechanisms through which daily physical activity is related to daily life satisfaction.

Life Satisfaction Across the Life Span

The results from this study align with recent evidence suggesting that life satisfaction is lower and/or decreasing during emerging and young adulthood and older adulthood (Baird et al., 2010; Gwozdz & Sousa-Poza, 2010). Our analysis of daily data collected from individuals age 18 to 90 found age differences in life satisfaction that followed a curvilinear trajectory, with lower life satisfaction during emerging and older adulthood and higher life satisfaction during young and middle adulthood (see Figure 2). These findings contradicted previous findings

regarding the trajectory of life satisfaction. Several studies have documented a U-shaped pattern where life satisfaction is lower during midlife and higher during emerging, young, and older adulthood with some studies suggesting that older adults are among the most satisfied across the adult life span (e.g., Blanchflower & Oswald, 2008; López Ulloa et al., 2013; Stone et al., 2010). Still other studies have found that life satisfaction is relatively stable until the mid-50s, at which point life satisfaction increases until the mid-60s, after which life satisfaction decreases (e.g., Frijters & Beatton, 2012). Increases in satisfaction during midlife found in this study may be the result of increased perceptions of control. As adults progress through middle adulthood feelings of control may strengthen particularly regarding work and finances, due to enhanced networks, more experience, and greater authority in the workplace as well as job security and subsequent financial stability (Lachman & Firth, 2004). Additionally, one such explanation for the decrease in life satisfaction in old age, known as the terminal decline process, suggests that an individual's cognitive abilities, well-being, and functioning decline sharply in the last years of life and can thus detract from life satisfaction (Birren & Cunningham, 1985; Gerstorf, Ram, Estabrook, et al., 2008; Gerstorf et al., 2010; Sliwinski et al., 2006; Wilson, Beckett, Bienias, Evans, & Bennett, 2003). Compared with previous studies that have not documented declines in life satisfaction in later life (i.e., Carstensen et al., 2011), our sample was recruited in a way that meant they were slightly more educated and financially secure. It may be that for the individuals in our sample experiencing declines in later life could feel as though they are losing more compared with less educated, financially secure samples and result in greater decreases in life satisfaction.

This pattern of differences in life satisfaction across the life span suggests the need for interventions to reduce the adverse effects of transitions into emerging adulthood and older adulthood. Emerging and older adults face many challenges that can interfere with developmentally appropriate goal pursuits and detract from life satisfaction (Baltes & Baltes, 1990; Heckhausen et al., 2010). For example, emerging adults, in order to form more coherent identities, often explore a variety of roles and relationships through a process of trial and error (Arnett, 2000). This freedom to make wrong turns down life's path may be incongruent with emerging adults' goal of forming a strong sense of self and, thus, detract from life satisfaction.

Based on results from this study, it appears that emerging adults would benefit from making small changes in daily physical activity to enhance life satisfaction. Small changes in daily life (i.e., taking the stairs instead of the elevator, walking to class instead of taking the bus) may have a greater impact on life satisfaction as opposed to more dramatic changes (i.e., adopting and maintaining a new exercise regimen for several months) and these small changes may be easier to incorporate into daily life, and thus be more sustainable as well. Additionally as adults transition into older adulthood, age-related declines in health and functioning may interfere with older adults' goal of healthy and successful aging and, thus, detract from life satisfaction (Rowe & Kahn, 1997). The findings here suggest that both small changes in daily physical activity as well as more substantial changes in usual levels of physical activity can enhance life satisfaction in older adulthood. Similar to emerging adults, incorporating small bouts of physical activity throughout the day such as walking the length of a supermarket aisle before shopping or parking in a spot further away from a building entrance can enhance life satisfaction in older adults. Additionally, for older adults, making changes in usual levels of physical activity by adopting

and maintaining a new exercise regimen or taking up a new sporting activity could also enhance life satisfaction.

Limitations

The sample of adults in this study was diverse with respect to age but fairly homogenous with respect to race/ethnicity. Both life satisfaction and physical activity have been shown to differ by race (e.g., Clemente & Sauer, 1976; Troiano et al., 2008). Additionally, participants' average level of physical activity in this study was equivalent to engaging in slightly more than two, 10-min bouts of moderate-intensity physical activity each day. Associations between physical activity and life satisfaction uncovered in this study may differ in subsamples of highly inactive or highly active adults. Future research should examine associations between physical activity and life satisfaction in more diverse populations.

Second, an underlying assumption of this study was that the emerging and young adults would eventually develop into the older adults in this study (i.e., age convergence; Sliwinski, Hoffman, & Hofer, 2010). To more precisely understand age-related differences in the between- and within-person associations between physical activity and life satisfaction, longitudinal data spanning decades of the life span will be needed.

Third, we did not attempt to distinguish daily life satisfaction from daily affect in this study. We suspect that momentary or daily ratings of life satisfaction and positive affect may be strongly associated but take no stand on the temporal precedence of either response because many third variables, such as physical activity, are likely associated with both. The contribution of this study is in showing the benefits of activity on an evaluative measure of subjective well-being across the life span (and in reconciling mixed results from previous studies). Future work will need to evaluate whether these evaluative and affective processes can be differentiated as well as whether they have differential impacts on outcomes (e.g., intrapersonal, social).

Fourth, physical activity was assessed via daily self-reports of the frequency of intensity-specific bouts. People tend to overestimate their physical activity on self-report measures compared with direct measures such as accelerometers (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2009; Prince et al., 2008). We also modified the LTEQ to capture daily physical activity as opposed to total bouts of activity across the week; however, we believe that the most likely consequence of the modification was increased score validity due to the reduced threat of retrospective recall bias (Matthews et al., 2012; Schwarz, 2007). Nevertheless, this measure is coarse and insensitive to the specific duration or type of activity. Additionally, this study did not control for adults' sedentary behavior—a related, but distinct, health behavior from physical inactivity. Future work should employ objective measures of physical activity and sedentary behavior, such as accelerometers and inclinometers.

Additionally, physical activity and life satisfaction were sampled at the end of each day in this study. Employing other sampling intervals could serve to further untangle associations between physical activity and life satisfaction. For example, continuously sampling physical activity and intermittently sampling life satisfaction throughout the day could shed light on the temporal process linking physical activity and life satisfaction.

In this study, we used a lifespan developmental framework to generate hypotheses about why life satisfaction might change across the adult life span. These theories emphasized the significance of motivation; however, we did not directly assess participants' motivation. Future work should investigate how physical activity impacts goal pursuits and how achieving or failing to achieve those goal pursuits impacts life satisfaction across the life span. An example of such research might investigate the role that physical activity plays in enhancing people's feelings of competence in their ability to complete activities of daily living, how those feelings of competence influence life satisfaction, and if those associations change across the life span.

Last, we cannot draw conclusions about causality because plausible third variables were not measured, the research design was not experimental, and the assessment schedule limited sensitivity to temporal ordering in the mediation analyses. Future research should control for other plausible third variables (e.g., sleep) as well as employ experimental designs at different points across the adult life span, manipulating physical activity to evaluate both the between- and within-person effect of physical activity on life satisfaction as well as the between- and within-person mechanisms of the association between physical activity and life satisfaction.

CONCLUSION

In conclusion, this study reconciled conflicting findings about relations between physical activity and life satisfaction across the life span. Daily changes in physical activity have important implications for overall health and well-being at any age, and regular physical activity becomes increasingly important for well-being as age-related declines set in, exacting a toll on people's physical and mental health. In addition to elaborating our theoretical understanding of life satisfaction, this study pointed to several strategies for improving life satisfaction across the adult life span.

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