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# PHYSICAL ACTIVITY, SEDENTARY BEHAVIOR, AND SATISFACTION WITH LIFE IN EMERGING ADULTS: UNTANGLING THEIR ASSOCIATIONS USING SELF-REPORT AND DIRECT MEASURES OF (IN)ACTIVITY

A Thesis in

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**ABSTRACT**

Satisfaction with life (SWL) is not only an important outcome in and of itself, but SWL also has implications for health, social relationships, community involvement, and productivity at work. Given the established benefits of SWL, it is important to understand the factors that influence SWL so strategies can be developed to enhance SWL. Physical activity (PA) is an established between-person, top-down predictor of SWL. More recently, the influence of PA has also been investigated from a within-person, bottom-up perspective. Although this approach has revealed a direct within-person association between PA and SWL in emerging adults, it has relied on self-reported PA and has not differentiated between low levels of activity and inactivity. A 14-day daily diary study was designed (1) to determine if the association between PA and SWL present using self-reported activity was also present using directly-measured activity and (2) to untangle the effects of PA and sedentary behavior (SB) on SWL. Results revealed that PA and SB had additive, within-person effects on SWL. People reported greater SWL on days when they were more active than was typical for them, and people reported lower SWL on days when they were more sedentary than was typical for them. Results were consistent across self-reported and directly-measured (in)activity. Additional analyses revealed that daily moderate-intensity PA appeared to drive the within-person association between self-reported PA and SWL; that the association between directly-measured moderate-intensity PA and SWL also was positive and trended toward significance. Findings from this study suggest that strategies to promote daily health and well-being should encourage emerging adults to incorporate bouts of moderate-intensity PA as well as to limit their sitting time throughout the day.

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# CHAPTER 1: BACKGROUND

Subjective well-being is colloquially referred to as happiness and represents a person's evaluation of his/her life (Diener, 1984, 2000). The evaluations that comprise subjective well-being are both affective and cognitive. Indeed, people experience abundant subjective well-being when they feel many pleasant and few unpleasant emotions (i.e., affective component) and when they are satisfied with their lives (i.e., cognitive component; Diener, 1984, 2000). Given that subjective well-being serves as a representation of whether or not a person is living the "good life," it makes sense that policy makers often note that the goal of policy should include enhancing citizens' subjective well-being as opposed to solely focusing on enhancing a country's economic prosperity.

One way to enhance subjective well-being is to attempt to improve the components that contribute to subjective well-being. Satisfaction with life (SWL) represents the cognitive component of subjective well-being and, consequently, is defined by Diener (1984) as, "a cognitive evaluation of one's life." Understanding the factors that contribute to SWL represents the first steps in developing practical strategies that can be used to enhance SWL and ultimately a person's happiness. This understanding of the influences on SWL is particularly relevant for emerging adults.

**Emerging Adulthood and Satisfaction with Life**

Emerging adulthood is a developmental period between the ages of 18 and 25 characterized by newly acquired independence from social roles and normative expectations, although residual financial dependence on family may still exist (Arnett, 1998, 2000). Exploration, in terms of a variety of life directions in love, work, and worldviews, also occurs during emerging adulthood. Emerging adulthood is a time of life when many different directions remain possible, when little about the future has been decided for certain, when the scope of independent exploration of life's possibilities is greater for most people than it will be at any other period of the life span (Arnett, 2000). In a sense, the independence and exploration that characterizes emerging adulthood represents a period of trial and error. In fact, this freedom to explore and make wrong turns down life’s path, may be one reason why SWL plummets during this developmental period. In a nationally-representative sample of adults across the United States, Stone et al. (2010) evaluated cross-sectional ratings of SWL and found that, from ages 18 to 25, SWL appears to decrease more sharply than at any other point in the adult lifespan. Although cross-sectional, this age-related trend suggests that emerging adults would perhaps most benefit from investigations into the factors that influence SWL.

**Influences on Satisfaction with Life**

Contemporary research predominantly frames influences on SWL as either top-down or bottom-up (Diener, 1984). Figure 1 illustrates the conceptual structure of top-down and bottom-up influences on SWL (adapted from Maher et al., in press). Top-down influences emphasize dispositional (i.e., time-invariant, between-person, trait-level) correlates of SWL, such as overall physical activity (PA) levels (i.e., more or less active people). Bottom-up influences of SWL reflect the impact that time-varying, within-person factors, such as daily life events, behaviors or states (i.e., exercising on a particular day), may have on SWL. To the extent that daily behaviors accrue over time to reflect dispositional tendencies, they may also produce a top-down effect on SWL.

The majority of research concerning SWL focuses on the influence of top-down factors as key contributors to SWL. This exclusive interest in top-down influences on SWL stems from early work measuring subjective well-being and SWL, that indicated these constructs remained stable over time. For example, Sandvik, Diener, and Seidlitz (1993) compared experience sampling method measures of SWL with one-time self-reported SWL, reports by friends and relatives, and people's memories of positive versus negative life events and found that these measures were moderately-to-strongly correlated. This early work helped to shape the field of research concerning SWL and its related influences by characterizing SWL as static and its influences as between-person processes. At the same time, this work set a precedent for discarding potentially-meaningful information regarding within-person variability in SWL.

More recently, however, there has been a burgeoning field interested in the dynamic properties of SWL as well as the influence of bottom-up, within-person processes on SWL. This line of thinking was prompted by earlier work from Schwarz and Strack (1999) which demonstrated that global measures of SWL can be influenced by current mood and other situational factors. Heller, Watson, and Ilies (2006) built upon that work by examining changes in SWL within people over time. Specifically, findings revealed that there was a moderate amount of within-person variability in SWL in momentary ratings of SWL over a three-week period. This work begs the question as to whether daily SWL is influenced by top-down processes, bottom-up processes, or both.

**Satisfaction with Life and Physical Activity**

PA is a health behavior that has the potential to be associated with SWL through either top-down or bottom-up processes, or even a combination of both. Chronic PA is associated with physiological effects that can result in improved physical health whereas acute PA is associated with increased feelings of energy as well as decreased feelings of anxiety and worry (Biddle, 2000; Dunn, Trivedi, & O’Neal, 2001; Li & Siegrist, 2012; Puetz, O’Connor, & Dishman, 2006; Taylor, Biddle, Fox, & Boutcher, 2000). Both chronic and acute PA could lead to changes in SWL.

Similar to other correlates of SWL, much of the previous research concerning the influence of PA on SWL has focused on the top-down influence of PA. For example, cross-sectional work by Elavsky and McAuley (2005) found that the relation between overall PA and SWL (i.e., a top-down, between-person association) was mediated by physical self-worth in middle-aged women. Prospective studies have yielded similar results. For example, at a 1-year follow-up of a PA intervention for older adults, Elavsky and colleagues (2005) found that self-efficacy and positive affect significantly mediated the association between overall PA and SWL, and that changes in positive affect mediated this relation over an additional 4 years of follow-up. Another prospective study of older women over a 24-month period found that the association between PA and SWL was mediated by self-efficacy and mental health status (McAuley et al., 2008).

Recently Maher et al. (in press) explored the relative influence of both top-down and bottom-up PA on SWL in two samples of emerging adults. Results from 8- and 14-day daily diary studies revealed that PA was directly associated with SWL through within-person processes. The top-down, between-person effects of PA were not significant in either study. These findings were robust even after controlling for competing top-down influences (e.g., sex, personality traits, self-esteem, body mass index, mental health symptoms, fatigue) and bottom-up influences (e.g., daily self-esteem, daily mental health symptoms, daily fatigue). Compared to previous studies by McAuley and colleagues, this intensive sampling of PA and SWL enabled Maher et al. to examine both between-and within-person associations between PA and SWL and ultimately to find a link between PA and SWL at the within-person level. Although this work extended the literature on PA and SWL, there were still limitations that constrained the conclusions which could be drawn from this work. Specifically, previous work concerning associations between PA and SWL was limited in that it relied solely on self-report measures of activity and it did not differentiate between low levels of PA and SB as it relates to SWL.

**Self-Report and Direct Measures of Physical Activity**

Self-report measures of PA provide many advantages to researchers who employ them. Not only are these measures easy to administer, but they are also inexpensive. Yet these self-report measures are not without flaws in terms of their ability to accurately capture PA. Self-reported measures of PA tend to emphasize moderate-to-vigorous intensity PA that occurs during leisure time (Troiano et al., 2008). Although leisure time activity is certainly important to capture, it is not the only type of activity that should be captured. Much of the activity that occurs during a day is a result of activity embedded within the context of daily living (O'Dougherty, Arikawa, Kaufman, Kurzer, & Schmitz, 2009). Examples of light-intensity PA embedded in daily life demands include activities like carrying groceries or walking to the water fountain. In fact, Owen et al. (2010) recently reported that adults spend the greatest proportion of their total activity engaged in these forms of light-intensity PA. Given the significant amount of time that adults spend in these light-intensity activities, it seems like a worthwhile form of activity to capture. Self-report measures of activity tend to underestimate this potentially valuable form of activity, whereas direct measures of PA (i.e., accelerometers) are able to capture it validly (Haskell, 2012).

Indeed, a recent review of the effects of light-intensity PA found that health benefits can accrue from the first increase in activity beyond baseline levels (Powell, Paluch, & Blair, 2011). Another review noted that health benefits related to cardiovascular functioning and kidney functioning can amass from as little as one hour of slow walking or other light-intensity PA per week (Warburton, Nicol, & Bredin, 2006). The positive impact of different intensity activities indicates that various types of activities of various intensities can play an influential role in a person's physical and mental health, and ultimately SWL. Given the limited correspondence between self-report and direct measures of activity (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2009; Prince et al., 2008) and the focus of self-report measures on leisure time activity, it is necessary to actually determine if the association between PA and SWL is the same depending on which measure (i.e., self-report, direct) of activity is used.

**Differentiating between Physical Activity and Sedentary Behavior and their Respective Influences on Satisfaction with Life**

PA and sedentary behavior (SB) are classified as distinct health behaviors (Marshall & Ramirez, 2011; Owen, Healy, Matthews, & Dunstan, 2010; Pate, O'Neill, & Lobelo, 2008). PA is a complex behavior that includes activities ranging in intensity from light to moderate to vigorous (Ainsworth et al., 1993, 2011). Light-intensity activities include standing, slow walking, and self-care activities and typically expend between 1.5 and 2.9 metabolic equivalent units (METs). Common moderate-intensity activities are brisk walking, household chores, and swimming and cycling for pleasure. These activities expend, on average, between 3.0 and 6.0 METs. Vigorous-intensity activities include running, aerobics, and heavy lifting and expend more than 6.0 METs. SB is defined as a unique class of behaviors that involve a seated or reclined posture and expend little energy (i.e., less than 1.5 METs) and is most commonly operationalized as time spent sitting (Sedentary Behavior Research Network, 2012). These definitions provide clear distinctions between PA and SB, yet the majority of research has not differentiated between low levels of PA and inactivity. In fact, only recently have these health behaviors been differentiated in research.

A critique of previous work examining the negative consequences associated with being sedentary is that these studies have not operationalized SB properly. In fact, one of the first studies linking SB to negative health outcomes was the Harvard Alumni Study which classified men as “sedentary” if they expended less than an estimated 2000 calories per week through walking, climbing stairs, and playing sports. This study concluded that men who were “sedentary” had a 31% greater risk of dying prematurely compared to active men (Paffenbarger, Hyde, Wing, & Hsieh, 1986). In the case of the Harvard Alumni Study, men who were engaging in walking, climbing stairs, and sports but not exceeding 2000 calories per week most likely had expected health consequences that were different from men who were engaging in no form of walking, climbing stairs, or sports but rather engaging in SB. Yet, the Harvard Alumni Study and many others like it since then have chosen to classify individuals as sedentary based on whether or not they reach a certain threshold of activity as opposed to their time spent sitting. In this context, low levels of weekly PA are conflated with SB and can lead to imprecise conclusions being drawn about the true nature of the association between SB and its related consequences (Rhodes, Mark, & Temmel, 2012).

This confounding of PA and SB is not only present in work examining the PA-well-being association; it has also appeared in studies investigating SB and its effect on well-being. Although a lack of PA and excessive SB have both been associated with deleterious effects on mental health and markers of well-being in separate samples (i.e., SWL; Depp, Schkade, Thompson, & Jeste, 2010; Frey, Benesch, & Stutzer, 2007; Paluska & Schwenk, 2000; Penedo & Dahn, 2005) it is unclear whether these associations are the result of low levels of PA or inactivity, as there has never been an examination of both health behaviors simultaneously. According to recent national panel data of directly-measured inactivity, emerging adults sit for nearly eight hours per day, which is equivalent to slightly more than half of their waking hours (Matthews et al., 2008). In fact, the eight hours of sitting per day during emerging adulthood is almost two hours more than the average amount of time spent sitting during childhood and early adolescence (Matthews et al., 2008). It may be that this increase in SB during this time is partly responsible for the concurrent decrease in SWL; however, PA levels also decline during this developmental period (Troiano et al., 2008). Given the measurement issues that pertain to accurately capturing SB, it is unclear whether low levels of activity, inactivity, or both are associated with SWL during emerging adulthood.

**Aims of the Thesis**

This thesis applies the top-down, bottom-up framework of influences on SWL to untangle the association between PA, SB, and SWL in emerging adults. The thesis aimed to extend previous work related to the within-person association between PA and SWL in several ways. First, the within-person association between PA and SWL was further explored by using both self-reported and directly-measured PA. Second, low levels of PA and SB were differentiated to gain a better understanding of the association between PA and SWL after accounting for the potential confounding influence of SB. Third, the potential interactions between PA and SB and their influence on SWL were explored. Finally, plausible third variables were controlled for to draw more precise conclusions about the nature of the association between PA, SB, and SWL.

# CHAPTER 2: MANUSCRIPT

Satisfaction with life (SWL) has been linked with a variety of important consequences, ranging from decreased depressive symptoms and worry to increased health and longevity across the adult lifespan (Diener & Chan, 2011; Lyubomirsky, King, & Diener, 2005). In fact, because of SWL's far-reaching implications in a variety of domains it is often considered a broad index of quality of life. Given the multitude of aforementioned outcomes associated with SWL, it would be valuable to understand the factors that influence SWL. This investigation is especially relevant for the emerging adult population because people's global evaluations of their well-being appear to worsen more from ages 18 to 25 years than any other time in the adult lifespan (Stone et al., 2010). Determining the factors that influence daily SWL during this stage is an important first step for explaining age-related differences in SWL across the adult lifespan and may reveal manageable daily behavior changes that emerging adults can make to enhance life satisfaction (e.g., walking to class instead of taking the bus). A 14-day daily diary study was conducted to gain a better understanding of the association between physical activity (PA), sedentary behavior (SB), and SWL in emerging adults using both self-report and direct measures of (in)activity.

**Satisfaction with Life and Physical Activity**

Subjective well-being is commonly conceptualized as "happiness" and incorporates both affective (i.e., pleasant and unpleasant emotions) and cognitive (i.e., SWL) components (Diener, 1984, 2000). Influences on SWL are customarily framed as either top-down or bottom-up, with top-down influences reflecting dispositional (i.e., time-invariant, trait-level, between-person) correlates of SWL and bottom-up influences focusing on the effect of time-varying factors, including daily life events, behaviors, or states, on SWL (Diener, 1984). Although top-down and bottom-up factors both represent viable influences on SWL, the majority of research concerning factors that influence SWL has been from a top-down perspective. This tendency to focus on top-down factors associated with SWL has left the influence of bottom-up factors relatively unexplored.

PA is a behavior that may exert a top-down or bottom-up influence, or a combination of both, on SWL. Much of the basis for an association between PA and SWL has stemmed from research in populations from the latter half of the adult lifespan. For example, cross-sectional and prospective studies on middle-aged women and older adults indicate that participating in regular PA is associated with enhanced SWL (Elavsky et al., 2005; Elavsky & McAuley, 2005; McAuley et al., 2008). Specifically, PA improves SWL in these populations through its influence on affect, self-worth, self-efficacy, and mental health. These effects could be attributed either to top-down processes (i.e., due to differences between more and less active people) or bottom-up processes (i.e., due to within-person changes in PA). Despite this possibility, previous research has not separated the top-down and bottom-up processes. Therefore, the underlying level of the effect is unclear. The amount of PA people participate in is known to change from day to day (Behrens & Dinger, 2003, 2005; Conroy, Elavsky, Hyde, & Doerksen, 2011; Sisson, McClain, & Tudor-Locke, 2008) and ratings of SWL have also been shown to vary across days (Heller et al., 2006; Maher et al., in press). Given PA's well-established between-person (i.e., top-down or trait-level) influence on SWL in older adults, it may be that daily PA may also be responsible for meaningful within-person changes (i.e., bottom-up or state-level influence) in daily SWL and points to the need to explore the potential impact of daily changes in PA on SWL.

Recently, Maher et al. (in press) investigated the association between daily PA and SWL in emerging adults. Emerging adulthood is a life stage characterized by a dramatic decline in SWL and this decline is steeper than at any other point in the adult lifespan (Stone et al., 2010).

Additionally, throughout emerging adulthood, both the level and intensity of PA decline (Troiano et al., 2008) and those changes in activity may help to explain the decrease in SWL during this developmental period. In two separate samples of emerging adults, controlling for a variety of established and plausible top-down and bottom-up influence on SWL, Maher et al. (in press) found that the association between PA and SWL existed at the within-person (i.e., bottom-up or state-level influences), but not the between-person level (i.e., top-down or trait-level influences). These findings indicated that there were no differences in SWL between more or less active people, but rather that SWL increased on days when people were more active than was typical for them. Although this research has helped to untangle the association between PA and SWL, it has had two significant limitations. Specifically, studies that have examined the within-person association between PA and SWL have (1) relied solely on self-report measures of activity and (2) failed to differentiate the effect of low levels of activity from inactivity.

**Self-Report and Direct Measures of Physical Activity**

Self -report measures of activity tend to emphasize moderate-to-vigorous intensity leisure time activities as opposed to light-intensity work- or transportation-related activities (Troiano et al., 2008). This focus on leisure-time activity means that low-level PA embedded in daily life demands, such as carrying groceries, walking to the water fountain or washing the dishes, are often not incorporated in self-report measures of activity. These light-intensity activities are, however, captured by direct measures of activity (Haskell, 2012). Given that light-intensity activity represents the greatest portion of daily PA (Owen, Sparling, et al., 2010), it is important to understand its association with SWL.

Light-, moderate-, and vigorous-intensity activities can produce positive physical and mental health benefits, which may enhance SWL. The health benefits of moderate- and vigorous-intensity PA are well established and include, but are not limited to, decreased risk of premature death, cardiovascular disease, diabetes, and depression (Haskell et al., 2007; Pate et al., 1995; Physical Activity Guidelines Advisory Committee, 2008). Although moderate- and vigorous-intensity activities are often stressed as a way to accrue health benefits, recent reviews provide evidence that even light forms of PA can produce significant health benefits (Powell et al., 2011). In fact, health benefits can amass from as little as one hour of slow walking or other light-intensity activities per week (Warburton et al., 2006). The positive impact of different intensity activities indicates that various types of activities of various intensities can play an influential role in a person's physical and mental health, and ultimately SWL. Given the limited correspondence between self-report and direct measures of activity (Adamo et al., 2009; Prince et al., 2008) and the focus of self-report measures on leisure time activity (Troiano et al., 2008), it is necessary to actually determine if the association between PA and SWL is the same depending on which measure (i.e., self-report, direct) of activity is used. Therefore, the first aim of this work was to replicate previous findings that the association between PA and SWL exists at the within-person level using a direct measure of activity. The first hypothesis of this study was that the positive within-person association between PA and SWL will be robust using both self-report and direct measures of PA.

**Differentiating between Physical Activity and Sedentary Behavior as it Relates to Satisfaction with Life**

PA and SB are incompatible health behaviors (Marshall & Ramirez, 2011; Owen, Healy, et al., 2010; Pate et al., 2008). PA is defined as a range of behaviors from light-intensity activities that include standing, slow walking, or self-care activities to vigorous-intensity activities that including running, aerobics, or heavy lifting. These activities typically expend more 1.5 metabolic equivalent units (METs; Ainsworth et al., 1993, 2011). Whereas, SB is defined as a unique class of behaviors that involve a seated or reclined posture and low levels of energy expenditure (i.e., less than 1.5 METs) and is most commonly operationalized as time spent sitting (Sedentary Behavior Research Network, 2012). Although PA and SB represent distinct behaviors, they have only recently been differentiated in research.

A critique of previous work examining the negative consequences associated with being sedentary is that these studies have not operationalized SB properly. Rather, these studies have chosen to classify individuals as sedentary based on whether or not they reach a certain threshold of activity as opposed to their actual time spent sitting. For example, a person may go for daily hour-long walks that are of light-intensity, but because this activity does not meet the criteria for moderate or vigorous activity, the person is not meeting PA guidelines and therefore considered "sedentary." In this instance, this person's level of activity and expected health consequences are most likely different from a person who engages in no form of activity and spends that time sitting; however, many studies would classify these two people as both being sedentary. In this context, low levels of PA are nested within SB and can lead to imprecise conclusions being drawn about the true nature of the association between SB and its related consequences (Rhodes et al., 2012).

The same dilemma presents itself concerning SB and its effect on well-being. Although a lack of PA is associated with deleterious effects on mental health and markers of well-being (i.e., SWL; Paluska & Schwenk, 2000; Penedo & Dahn, 2005) it is unclear whether these associations are the result of low levels of activity or inactivity (i.e., SB). Recent national panel data of directly-measured inactivity indicate that emerging adults tend to sit on average between 7.5 and 8.0 hours per day, a duration equivalent to more than 50% of their waking hours (Matthews et al., 2008). Upon entering emerging adulthood, emerging adults are sedentary for an average of 2 hours more per day then they were during childhood and early adolescence (Matthews et al., 2008). This increase in sedentary time may be responsible for worsening SWL during emerging adulthood; however, activity levels decline during this point in the lifespan as well (Troiano et al., 2008). Given the measurement issues that pertain to accurately capturing SB, it is unclear whether inactivity, low levels of activity, or both are associated with SWL. It may also be that SB confounds the association between PA and SWL. Therefore the second aim of this work was to extend previous work by determining if the association between PA and SWL still remains after controlling for the plausible confounding influence of SB. It was hypothesized that the bottom-up (within-person) association between PA and SWL will remain after controlling for SB.

**Satisfaction with Life and Sedentary Behavior**

Although there is limited research concerning the relation between SB and SWL in adults, there appears to be a negative association between SB and SWL. People who tend to engage in greater amounts of SB on average also tend to experience lower SWL compared to people who are less sedentary (Depp et al., 2010; Frey et al., 2007). Similar to research concerning the association between PA and SWL, the few studies that have investigated the association between SB and SWL have focused on the top-down or between-person association between SB and SWL, without attending to the potential impact of daily or bottom-up association between SB on SWL. Chronic SB has well-established health consequences that can detract from SWL (e.g., increased risk for premature death, cardiovascular disease, metabolic syndromes, decreased mental health; Healy et al., 2008; Healy, Matthews, Dunstan, Winkler, & Owen, 2011; Katzmarzyk, Church, Craig, & Bouchard, 2009; Lynch, 2010; Teychenne, Ball, &

Salmon, 2010; Thorp, Owen, Neuhaus, & Dunstan, 2011; van der Ploeg, Chey, Korda, Banks, & Bauman, 2012; van Uffelen et al., 2010), but acute SB (i.e., sitting more than usual on a given day) has negative health consequences that also may diminish SWL (e.g., decreased lipid metabolism, decreased glucose uptake and insulin sensitivity; Bey & Hamilton, 2003; Hamilton, Etienne, McClure, Pavey, & Holloway, 1998; Zderic & Hamilton, 2006). Furthermore, as daily SB unfolds over time, the amount of time spent sitting each day begins to be incorporated or reflected as part of overall or average SB. Therefore, it is possible that the top-down (between-person) association of SB and SWL found in previous research is merely an artifact of the bottom-up (within-person) association over time. The top-down association may simply be driven by the bottom-up, within-person association between SB and SWL, but because the top-down and bottom-up influences of SB have not been teased apart, the effect appears to be the result of a top-down association. This complexity points to the need to control for both the top-down and bottom-up influence of SB when determining the nature of the association between PA and SWL. The third hypothesis of this study was that the within-person association between PA and SWL will remain positive and significant after controlling for the top-down and bottom-up influence of SB.

It is also unclear whether the magnitude of the association between PA and SWL is dependent upon the level of SB a person engages in. Although it is well-established that SB has negative physical health consequences independent of PA levels, the potential interaction between PA and SB on SWL has been largely unexplored. Previous work has indicated that the association between PA and SWL in emerging adults is driven by the bottom-up, within-person association (Maher et al., in press). Therefore it would be worthwhile to investigate the potential interaction between daily PA and daily SB as well as the potential interaction between daily PA and overall SB on SWL.  It may be that on days when people engage in more SB than is typical for them the strength of the association between daily PA and SWL decreases compared to days when people are less sedentary than usual. It may also be that the strength of the association between daily PA and SWL is weaker for people who tend to be highly sedentary overall compared to those who tend to be less sedentary overall. The third aim of this work is to explore the interaction between daily PA and daily SB and daily PA and overall SB on SWL. The fourth hypothesis of this study was that, on days when people engaged in more SB than usual, the association between daily PA and SWL would decrease compared to days when people were less sedentary than usual. The fifth hypothesis of this study was that for people who engage in more SB overall, the association between daily PA and SWL would increase compared to people who engage in less SB overall.

**The Present Study**

A 14-day daily diary study was conducted to better understand the associations between PA, SB, and SWL. This study seeks to replicate and extend findings from previous work that the association between PA and SWL exists at the within-person level using both self-report and direct measures of activity. Because self-report and direct measures of activity capture specific and often unique levels and intensities of activity, it is unclear if the PA captured by these methods relate to SWL in the same way (Haskell, 2012; Troiano et al., 2008).  It was hypothesized that both self-report and direct measures of activity would find a positive association between PA and SWL at the within-person level, indicating that, on days when people were more physically active than usual, they report greater SWL.

Second, this study differentiated between low level PA and SB to determine if the association between PA and SWL was robust after controlling for the top-down and bottom-up influence of SB. It was hypothesized that the within-person association between PA and SWL would remain after controlling for the top-down and bottom-up influence of SB.

Third, this study conducted an exploratory analysis examining the interactive effects of PA and SB on SWL. It was unclear whether the effect of PA on an indicator of well-being (i.e., SWL) would be independent of the level of SB. Previous work has indicated that the association between PA and SWL is impacted by people's daily PA rather than their PA over time (Maher et al., in press). Therefore, this exploratory analysis focused on the interaction between daily PA and overall SB as well as the interaction between daily PA and daily SB and their respective influence on SWL. It was hypothesized that on days when people engage in more SB than usual and for people who engage in more SB overall, the association between daily PA and SWL will decrease compared to days when people are less sedentary than usual or less sedentary overall.

As previously mentioned the influences on SWL include both top-down and bottom-up processes. Although PA is an established predictor of SWL, other correlates of SWL may provide plausible top-down and bottom-up influences on SWL. Therefore, this study will strengthen confidence in conclusions about (in)activity-SWL relations by controlling for an additional set of plausible top-down and bottom-up influences. Both mental and physical health have been associated with health behaviors (i.e., PA and SB) and SWL (McAuley et al., 2006); although the majority of this work has examined these associations through a top-down lens. It may be that mental and physical health each act as a third variable that drives the association between health behaviors and SWL through a top-down or bottom-up association. Therefore mental and physical health were controlled in these analyses for to rule out these plausible third variables that could account for associations between PA and SWL.

Two other variables were also controlled for to strengthen findings about the relation between PA and SWL. Health behaviors in the emerging adult population can be affected by daily events and constraints in the social calendar (e.g., extracurricular activities, class/work schedules). Day of the week was controlled for to account for changes in activity as a result of the social calendar (Behrens & Dinger, 2003, 2005; Conroy et al., 2011; Sisson et al., 2008). Likewise, reactivity as a result of participating in a repeated measures study may also impact activity through processes like self-monitoring (Motl, McAuley, & Dlugonski, 2012). Accordingly, the day in study sequence was controlled for to account for changes in activity as a result of study participation. All hypothesized associations between (in)activity and SWL were expected to be robust after controlling for these variables.

# Methods

## Participants and Procedures

Participants were 128 university students enrolled in undergraduate courses that participated in a daily diary study as part of a class project. All but one participant indicated that they were capable of performing normal PA. Another participant did not give permission to use his data for research purposes. Those two participants were excluded from analyses, resulting in a sample of 75 women and 53 men. The sample consisted of predominately White (87%), non-Hispanic (96%) women (58%) in their third (16%) or fourth (78%) year of schooling.

At an introductory lab session, participants provided informed consent, permission for their data to be used for research purposes, and demographic information. At this introductory session participants were also trained how to access a secure website at the end of every day between 7:00pm and 4:00am over the course of the 14-day study to complete a brief questionnaire about their behaviors and feelings for that day. Participants were instructed to wear the accelerometer on their right hip during all waking hours for the duration of the study, except for times when participants were bathing/showering or engaging in other water-related activities. Participants provided self-reported data for a total of 1,653 of the 1,792 possible person-days (93% response rate) and 69% of participants (*n* = 88) provided data on 13 days of the 14 day study ($Median_{\#\ of\ days}$ = 14, $Mean_{\#\ of\ days}$ = 12.91, $SD_{\#\ of\ days}$ = 1.44). Participants also provided directly-measured data for a total of 1,485 of the 1,792 possible person-days (83% response rate) and 56% of participants (*n* = 71) provided data on 12 days of the 14 day study ($Median_{\#\ of\ days}$ = 13, $Mean_{\#\ of\ days}$ = 11.69, $SD_{\#\ of\ days}$ = 2.92).The local institutional review board approved all study protocols.

**Measures**

***Satisfaction with Life.*** Daily SWL 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"). Maher et al. (in press) found that this item best captured the latent SWL factor while reducing the participant burden inherent in completing measures with multiple items assessing the same construct. Participants rated the item on a visual analogue scale ranging from 0 (s*trongly disagree*) to 100 (*strongly agree*).

***Physical Activity.*** Daily self-report PA was assessed using a version of the International Physical Activity Questionnaire (IPAQ; Booth, 2000), a validated measure of adult PA (Craig et al., 2003). The IPAQ was modified to focus on daily instead of weekly PA. This daily adaptation reduces the threat of retrospective bias and has been used in previous research (Maher et al., in press). Prompted with definitions and examples of different intensity (i.e., vigorous, moderate, walking) physical activities (e.g., "Think about activities which take *vigorous* physical effort that you did today. Vigorous physical activity is defined as activities that take hard physical effort and make you breathe much harder than normal. Vigorous physical activities may include heavy lifting, digging, aerobics, or fast bicycling."), participants reported the total amount of time that they had spent engaged in each intensity physical activities for at least 10 minutes at a time that day. Standard data processing procedures for the IPAQ were used to convert duration of activity into metabolic equivalents. Activity times were weighted by standard MET estimates (vigorous PA = 8, moderate PA = 4, walking = 3.3) and summed to create a PA MET•minutes/day score (Sjöström et al., 2002, 2005).

Daily direct PA was measured using a triaxial accelerometer (Actigraph model GT3X, Pensacola, FL). The accelerometer data were aggregated into one minute epochs and processed and analyzed using the Actilife data analysis software from Actigraph (version 5.1.5). Data were screened to determine valid days which were defined as days with more than 10 hours of valid wear time. Activity counts were adjusted for valid hours, in the form of an average count per valid hour. This adjustment eliminates the potential confound of high activity counts being the result of accruing more valid wear time hours rather than a result of accruing more activity.

***Sedentary Behavior.*** Daily SB was assessed using a version of the IPAQ (Booth, 2000). Rosenberg et al. (2008) found that the IPAQ-based weekly measure of SB was a reliable measure of sitting time. The item assessing sitting time was modified to focus on daily instead of weekly SB. Prompted with examples of opportunities to be sedentary (i.e., Think about the time you spent *sitting* today. This includes times spent at work, at home, while doing course work, and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting down to watch television."), participants reported their total amount of time they had spent engaged in SB.

Daily direct SB was also measured using a triaxial accelerometer (Actigraph model GT3X, Pensacola, FL). Data processing and analysis of valid hours were also the same as those described in the measure of direct PA. Using this direct measure of SB, SB was defined as < 100 counts·min$^{-1}$ (Freedson, Melanson, & Sirard, 1998). Although there has been debate about the best cut-off point to define SB, the < 100 counts·min$^{-1}$ criterionhas been shown to be both a sensitive and specific measure of SB across days (Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011).

***Mental & Physical Health Symptoms.*** The Health-Related Quality of Life Questionnaire was designed to capture mental and physical health symptoms leading a person to seek care (Hennessy, Moriarty, Zack, Scherr, & Brackbill, 1994). Two items were used from this scale to assess daily mental and physical health symptoms. These items were modified to reflect daily symptoms as opposed to symptoms over the past thirty days, which the measure was originally designed for. Daily mental health symptoms were assessed using the single item, "Today, my mental health was NOT GOOD." Daily physical health symptoms were assessed using the single item, "Today, my physical health was NOT GOOD." Participants rated each item on a scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

**Data Analysis**

Multilevel models (Snijders & Bosker, 1999) were used to examine between- and within-person associations between PA and SWL, while accommodating the nested nature of the data (days nested within-persons). Models were estimated using SAS 9.2 PROC MIXED (Littell, Milliken, Stroup, & Wolfinger, 1996), with missing observations (self-report: < 1%, $n_{observations} = 10$; directly-measured: 7%, $n_{observations} = 101$) treated as missing completely at random. The final sample consisted of 1,643 daily self-reports and 1,384 daily direct measures of (in)activity from 128 persons. In accordance with standard multilevel modeling practice, pseudo-$R^2$, the additional proportion of variance explained by the predictors (e.g., daily PA, SB) compared to a baseline model, was considered as an indicator of effect size (see Snijders & Bosker, 1999) .

***Data preparation.*** To separately test between- and within-person associations, daily ratings of PA, SB, mental and physical health symptoms were person centered (Bolger, Davis, & Rafaeli, 2003; Schwartz & Stone, 1998). For example, person *i*'s overall level of PA ($Overall\ PA_i$) was calculated as the within-person mean of her daily responses across the 14 days and each person's daily level of PA ($Daily\ PA_{di}$) was calculated as the deviation of day *d*'s score from the individual mean. Therefore, all constructs referred to at the daily level (i.e., daily PA, daily SB, daily mental health symptoms, daily physical health symptoms) are daily deviations from the individual's average across days. For the purpose of this study, we considered within-person mean scores across the 14 days as indicative of top-down factors (i.e., differentiating more or less active *people*) and daily deviations as indicative of bottom-up factors (i.e., differentiating more or less active than usual *days*).

For variables with skewed distributions, power law transformations were conducted using the Box-Cox method to find the optimal normalizing transformation for each variable (Box & Cox, 1964; Osborne, 2010). Transformed values were used to calculate correlations and estimate parameters in the multilevel models.

Six dummy variables representing the day of the week were created as within-person variables. Thursday served as the reference category because the majority of participants began data collection on a Thursday. To control for the possibility that health behaviors changed as a result of, or were reactive to, participating in the study we created another within-person variable to represent the sequence of the day in the study.

***Associations between Physical Activity, Sedentary Behavior, and Satisfaction with Life.*** To accomplish the objectives of this study a series of increasingly complex analyses were conducted. Self-reported and direct measures of (in)activity were used in separate models. The final model is presented in equations 1 through 14:

Level-1: $SWL_{di} = \beta_{0i} + \beta_{1i}(\text{Daily PA}_{di}) + \beta_{2i}(\text{Daily SB}_{di}) + \beta_{3i}(\text{Daily PA}_{di} \text{ x Daily SB}_{di}) + \beta_{4i}(\text{Daily Mental Health Symptoms}_{di}) + \beta_{5i}(\text{Daily Physical Health Symptoms}_{di}) + \beta_{6i}(\text{Monday}_{di}) + \beta_{7i}(\text{Tuesday}_{di}) + \beta_{8i}(\text{Wednesday}_{di}) + \beta_{9i}(\text{Friday}_{di}) + \beta_{10i}(\text{Saturday}_{di}) + \beta_{11i}(\text{Sunday}_{di}) + \beta_{12i}(\text{Day in Study}_{di}) + e_{di}$ (1)

Level-2: $\beta_{0i} = \gamma_{00} + \gamma_{01}(\text{Overall PA}_{i}) + \gamma_{02}(\text{Overall SB}_{i}) + \gamma_{03}(\text{Overall Mental Health Symptoms}_{i}) + \gamma_{04}(\text{Overall Physical Health Symptoms}_{i}) + u_{0i}$ (2)

$\beta_{1i} = \gamma_{10} + \gamma_{11}(\text{Overall SB}_{i}) + u_{1i}$ (3)

$B_{2i} = \gamma_{20} + u_{2i}$ (4)

$B_{3i} = \gamma_{30}$ (5)

$B_{(4\text{-}5)i} = \gamma_{(4\text{-}5)0} + u_{(4\text{-}5)i}$ (6-7)

$B_{(6\text{-}12)i} = \gamma_{(6\text{-}12)0}$ (8-14)

where $\gamma_{01}$ to $\gamma_{04}$ represent the top-down trait influences of PA, SB, mental health symptoms, and physical health symptoms (between-person effects) on daily SWL ($SWL_{di}$), $\gamma_{10}$ to $\gamma_{120}$ represent the average strength of the bottom-up influences of state PA, SB, the interaction between PA and SB, mental health symptoms, physical health symptoms, day of the week, and day in study sequence (average within-person effects) on daily SWL, $\gamma_{11}$ represents the average strength of the top-down trait influence of SB on the association between bottom-up, state PA and daily SWL, and $u_{0i}$ to $u_{2i}$ and $u_{4i}$ to $u_{5i}$ are individual-level residual deviations that are uncorrelated with the day-level residuals $e_{di}$. The residual variance for SB in models using directly-measured data, $u_{2i}$, and the within-person interaction term between PA and SB, $u_{3i}$, were removed to accommodate the limited sample size, and the residual variance for the day of week and day in study sequence (i.e., $u_{6i} - u_{12i}$) were treated as unconditional fixed effects to reduce model complexity.

The first objective of this study was to determine if the association between PA and SWL existed at the within-person level using both self-report and direct measures of activity. Therefore in this first set of analyses, daily SWL was regressed on overall and daily PA. Parameters $\gamma_{00}$, $\gamma_{01}$, $\gamma_{10}$, $u_{0i}$, and $e_{di}$ were estimated.

The second objective of this study was to determine if the association between PA and SWL was robust after controlling for the top-down and bottom-up influence of SB. Therefore, in the second set of analyses, daily SWL was regressed on overall and daily PA, controlling for individual differences in SB and daily deviations in SB. Parameters $\gamma_{00}$, $\gamma_{01}$, $\gamma_{10}$, $\gamma_{02}$, $\gamma_{20}$, $u_{0i}$, $u_{1i}$, and $e_{di}$ were estimated.

The third objective of this study was to explore the interaction between PA and SB and its association with SWL. Therefore, in the third set of analyses, daily SWL was regressed on overall and daily PA, controlling for individual differences in SB and the interaction between individual differences in PA and daily SB and daily deviations in SB and the interaction between daily PA and daily SB. Parameters $\gamma_{00}$, $\gamma_{01}$, $\gamma_{10}$, $\gamma_{02}$, $\gamma_{20}$, $\gamma_{11}$, $u_{0i}$, $u_{1i}$, and $e_{di}$ were estimated.

The final objective of this study was to further validate the findings concerning the association between PA and SWL by controlling for an additional set of plausible top-down and bottom-up influences. Therefore, in the fourth set of analyses, daily SWL was regressed on overall and daily PA, controlling for individual differences in SB, mental and physical health symptoms, and the interaction between individual differences in SB and daily PA and daily deviations in SB, mental and physical health symptoms, the interaction between daily PA and daily SB, and day of week and day in study effects. All parameters presented in the final model were estimated.

## Results

Descriptive statistics are displayed in Table 1. On average, participants experienced moderate-to-high levels of SWL (75.56 on a 0 to 100 scale). Participants were also fairly active, on average. Self-reported PA indicated that participants engaged in the equivalent of an hour and a half of walking and moderate PA each day. Directly-measured activity counts indicated that participants engaged in similar amounts of activity and the distribution of time spent in light, lifestyle, moderate, vigorous, and very vigorous activities compared with those from the nationally-representative NHANES sample (Troiano et al., 2008). Participants also reported sitting for almost six waking hours each day whereas accelerometer data indicated that participants sat for almost two-thirds of their waking hours each day. These accelerometer-derived sedentary times correspond with findings from Matthews et al. (2008) that young adults (age 20-29) sit for approximately 55% of their waking hours.

Significant skew was present in all predictor variables ($p < .05$). Using the Box-Cox method (Box & Cox, 1964; Osborne, 2010), the optimal power-law transformations were determined to normalize the distributions of self-reported PA ($\lambda = 0.30$), directly-measured PA ($\lambda = 0.30$), self-reported SB ($\lambda = 0.60$), directly-measured SB ($\lambda = 2.00$), mental health symptoms ($\lambda = -0.10$), and physical health symptoms ($\lambda = 0.10$). Transformed variables were used to estimate correlations and multilevel models.

Two types of bivariate correlations were estimated for descriptive purposes. The first set (below diagonal in Table 1) ignored the nesting of days within people as a result of the intensive sampling design of this daily diary study. The second set (above diagonal in Table 1) represents the associations between within-person means of each variable and is insensitive to within-person variation in ratings. Because of the limitations inherent in each set of estimates, correlations are interpreted descriptively but not inferentially. In both sets of correlations, PA and SWL had a weak positive association (*r*s ≥ .03). Conversely, SB and SWL tended to have a weak negative association (except for within-person association between directly-measured SB and SWL; *r*s ≤ -.05). It should also be noted that self-report and direct measures of PA were correlated only moderately (*r*s = .27 and .42). Similarly, self-report and direct measures of SB were correlated moderately (*r*s = .33 and .25).

**Physical Activity Predicting Satisfaction with Life**

In the first set of analyses, the association between self-reported and directly-measured PA and SWL was examined. Results from the multilevel models are displayed in Table 2. Both self-reported and directly-measured PA were associated with SWL at the within-person level, but neither measure was associated with SWL at the between-person level. These results suggested that overall levels, or the top-down influence, of activity were not predictive of SWL (self-report: $\gamma_{01} = 0.22$, $p = .50$; directly-measured: $\gamma_{01} = -0.02$, $p = .91$) whereas daily deviations in PA, or the bottom-up influence of PA, were predictive of SWL (self-report: $\gamma_{10} = 0.80$, $p < .001$; $\gamma_{10} = 0.38$, $p < .001$), so that on days when people exercised more than they typically did, they also tended to experience greater SWL. The random effect for the association between daily PA and SWL was significant (self-report: $\sigma^2_{u1} = 0.94$, $p < .001$; directly-measured: $\sigma^2_{u1} = 0.11$, $p < .001$), indicating that the within-person association between PA and SWL varied between-people.

**Physical Activity and Sedentary Behavior Predicting Satisfaction with Life**

A second set of multilevel analyses was conducted focusing on the association between PA and SWL while controlling for SB. Results from the multilevel models are displayed in Table 3. The bottom-up, within-person association between PA and SWL remained significant after controlling for the top-down and bottom-up influence of SB in both self-reported ($\gamma_{10} = 0.57$, $p < .001$) and directly-measured ($\gamma_{10} = 0.22$, $p < .001$) PA. Top-down, between-person differences in overall levels of PA were not significantly associated with SWL in either measure of activity (self-report: $\gamma_{01} = 0.25$, $p = .45$; directly-measured: $\gamma_{01} = 0.11$, $p = .67$). Bottom-up or daily SB was negatively associated with SWL using both measures of inactivity (self-report: $\gamma_{20} = -0.21$, $p < .001$; directly-measured: $\gamma_{20} = -0.005$, $p < .001$), indicating that on days when people sat more than was typical for them, they also tended to experience lower SWL. There was no top-down or overall effect of SB on SWL in the models with self-reported ($\gamma_{02} = 0.03$, $p = .82$) or directly-measured ($\gamma_{01} = 0.13$, $p = .45$) inactivity. The random effect for the association between daily PA and SWL and the association between daily SB and SWL was significant (self-report: $\sigma^2_{u1} = 0.67$, $p < .05$, $\sigma^2_{u2} = 0.11$, $p < .05$; directly-measured: $\sigma^2_{u1} = 0.15$, $p < .05$), indicating that these associations varied between-people. These significant random effects also raised the possibility that the within-person association between PA and SWL varied as a function of a person's SB.

A third set of analyses was conducted to explore a potential interaction between PA and SB on SWL. The analyses investigated the interaction between daily PA and overall SB on SWL as well as the interaction between daily PA and daily SB on SWL using both self-reported and directly-measured (in)activity. Results from the multilevel model are shown in Table 4. There was no interaction between daily PA and overall SB or daily PA and daily SB in either measure of (in)activity (self-report: $\gamma_{11} = 0.01$, $p = .69$, $\gamma_{30} = 0.01$, $p = .69$; directly-measured: $\gamma_{11} = 0.01$, $p$

= .64, $\gamma_{30}$ = 0.01, $p$ = .77). The bottom-up, within-person associations found in previous analyses between daily PA and SWL (self-report: $\gamma_{10}$ = 0.56, $p$ < .001 ; directly-measured: $\gamma_{10}$ = 0.22, $p$ < .05,); and daily SB and SWL (self-report: $\gamma_{20}$ = -0.21, $p$ < .001; directly-measured: $\gamma_{20}$ = -0.005, $p$ < .001) were significant in this third set of analyses. Also similar to previous results were the null findings related to the top-down, between-person association between daily health behaviors and SWL. The results were consistent across both measures of (in)activity (self-report: $\gamma_{01}$ = 0.25, $p$ = .46, $\gamma_{02}$ = 0.01, $p$ = .92; directly-measured: $\gamma_{01}$ = 0.11, $p$ = .66, $\gamma_{02}$ = 0.01, $p$ = .49). The random effect for the association between daily PA and SWL and the association between daily SB and SWL were significant (self-report: $\sigma^2_{u1}$ = 0.68, $p$ < .05, $\sigma^2_{u2}$ = 0.11, $p$ < .05; directly-measured: $\sigma^2_{u1}$ = 0.15, $p$ < .05).

**Physical Activity, Sedentary Behavior, and Mental and Physical Health Predicting Satisfaction with Life**

The fourth set of analyses was designed to strengthen our finding concerning the nature of the association between PA and SWL by controlling for an additional set of plausible third variables. Therefore, these analyses controlled for the top-down and bottom-up influence of mental and physical health symptoms as well as the day-of-week and day in the study. Results from the multilevel models are presented in Table 5. The bottom-up, within-person association between PA and SWL, found in previous analyses, was significant even after controlling for those additional top-down and bottom-up factors, indicating that on days when people engaged in more PA than they usually did, they also tended to experience greater SWL (self-report: $\gamma_{10}$ = 0.35, $p$ < .05; directly-measured: $\gamma_{10}$ = 0.14, $p$ < .05). The bottom-up, within-person association between SB and SWL also remained significant, so that on days when people sat more than was typically for them, they also tended to experience less SWL (self-report: $\gamma_{20}$ = -0.12, $p$ < .05;

directly-measured: $\gamma_{20}$ = -0.003, $p < .05$). Consistent with previous analyses, neither the top-down influence of overall PA (self-report: $\gamma_{01}$ = 0.19, $p$ = .43; directly-measured: $\gamma_{01}$ = -0.08, $p$ = .65) nor that of overall SB (self-report: $\gamma_{02}$ = 0.04, $p$ = .63; directly-measured: $\gamma_{02}$ = -0.01, $p$ = .69) were significant predictors of SWL. None of the potential interactions were significant (self-report: $\gamma_{11}$ = -0.01, $p$ = .88, $\gamma_{30}$ = 0.01, $p$ = .58; directly-measured: $\gamma_{11}$ = -0.01, $p$ = .85, $\gamma_{30}$ = -0.01, $p$ = .42).

Mental health symptoms, both overall (self-report: $\gamma_{04}$ = -17.24, $p < .001$; directly-measured: $\gamma_{04}$ = -21.51, $p < .001$) and daily (self-report: $\gamma_{40}$ = -12.46, $p < .001$; directly-measured: $\gamma_{40}$ = -13.04, $p < .001$), appeared to negatively affect SWL so that people who experienced greater mental health symptoms overall tended to experience lower SWL and that, on days when people reported more mental health symptoms than was typical for them, they also rated their SWL lower. Physical health symptoms had a negative, bottom-up, within-person association with SWL (self-report: $\gamma_{50}$ = -3.16, $p < .05$; directly-measured: $\gamma_{50}$ = -2.76, $p < .05$), but not a top-down, between-person association (self-report: $\gamma_{05}$ = -5.25, $p$ = .11; directly-measured: $\gamma_{05}$ = -1.30, $p$ = .70).

The within-person effect of PA (self-report: $\sigma^2_{u1}$ = 0.68, $p < .05$; directly-measured: $\sigma^2_{u1}$ = 0.07, $p < .05$), SB (self-report: $\sigma^2_{u2}$ = 0.04, $p < .05$), and mental health symptoms (self-report: $\sigma^2_{u4}$ = 115.19, $p < .001$; directly-measured: $\sigma^2_{u4}$ = 113.41, $p < .05$) all varied significantly between people.

As indicated by the pseudo $R^2$, the final model utilizing self-reported measure of (in)activity to predict SWL accounted for approximately 35% of the variance in SWL, with daily PA and SB combining to account for 46% of the explained variance. Similarly, the final model using directly-measured (in)activity to predict SWL accounted for approximately 37% of the variance in SWL, with daily PA and SB combining to account for 47% of the explained variance.

**Additional Analyses**

These data are observational in nature, so statements regarding causality cannot be drawn; however, alternative temporal sequences can be evaluated to strengthen the argument that behavior (i.e., PA, SB) might also influence evaluations (i.e., SWL) as opposed (or in addition) to our hypothesized model of evaluations influencing behavior. Consequently, a multivariate multilevel analysis regressing PA and SB on previous day's SWL was conducted. Table 6 reveals the results from the multivariate multilevel model using self-reported and directly-measured (in)activity. Neither the between- nor within-person association between previous day's SWL and subsequent day's PA were significant using self-report ($\gamma_{01}$ = 0.03, $p$ = .28; $\gamma_{10}$ = 0.01, $p$ = .71) or directly-measured activity ($\gamma_{01}$ = 0.02, $p$ = .63; $\gamma_{10}$ = 0.01, $p$ = .77). Results also indicated that there was not a significant between-person association between previous day's SWL subsequent day's SB. This finding was similar for both self-reported ($\gamma_{02}$ = -0.04, $p$ = .60) and directly-measured ($\gamma_{02}$ = 0.02, $p$ = .56) SB. Results were mixed for the within-person association between previous day's SWL and subsequent day's SB. Previous day's SWL was negatively associated with subsequent day's self-reported SB ($\gamma_{20}$ = -0.04, $p$ = .02), meaning that on days when people were more satisfied than usual, they also tended to self-report less time spent sitting the following day.   This within-person association, however, was not present using directly-monitored sitting time ($\gamma_{20}$ = -0.01, $p$ = .40).

A final additional analysis was conducted to determine the intensity-specific effects of PA on SWL. The intensity of activity for self-reported PA was separated into vigorous PA, moderate PA, and walking based on responses to the short-form IPAQ (Booth, 2000). Intensity of activity was determined for directly-measured activity using previously developed cutoffs by Freedson et al. (1998) for light, moderate, and vigorous intensity activity (i.e., counts of 100-1951, 1952-5724, and 5725+, respectively). These models also included a measure of SB as well as other control variables previously outlined. Light-intensity activity was not included in the intensity analysis of directly-measured PA because intensity-specific PA is simply a function of the percentage of waking hours spent in each type of intensity and its inclusion would create multicollinearity problems. Results are displayed in Table 7. Neither walking (self-report: $\gamma_{03}$ = 0.24, $p$ = .53, $\gamma_{30}$ = 0.26, $p$ = .10), nor vigorous- (self- report: $\gamma_{01}$ = 12.11, $p$ = .10, $\gamma_{10}$ = 3.48, $p$ = .10; directly-measured: $\gamma_{01}$ = -0.21, $p$ = .93, $\gamma_{10}$ = -0.29, $p$ = .65) intensity activity were associated with SWL at either the between- or within-person level. Self-reported moderate-intensity activity was significantly associated with SWL at the within-person level ($\gamma_{02}$ = 0.64, $p$ = .02) but not at the between-person level ($\gamma_{20}$ = -0.28, $p$ = .72). The association between directly-measured moderate-intensity activity and SWL trended toward significance at the within-person level ($\gamma_{02}$ = 0.61, $p$ = .06) and was not significant at the between-person level ($\gamma_{20}$ = 1.00, $p$ = .46). A within-person association (self-report: $\gamma_{40}$ = -0.12, $p < .001$; directly-measured: $\gamma_{40}$ = -0.01, $p < .001$), but not between-person association (self-report: $\gamma_{04}$ = .09, $p$ = .30; directly-measured: $\gamma_{04}$ = 0.01, $p$ = .82), was found between SB and SWL in both measures of inactivity. Similar to previous results, the associations between mental health symptoms and SWL existed at the between- (self-report: $\gamma_{05}$ = -19.29, $p < .001$; directly-measured: $\gamma_{05}$ = -19.99, $p < .001$), and within-person (self-report: $\gamma_{50}$ = -12.96, $p < .001$; directly-measured: $\gamma_{50}$ = -12.88, $p < .001$), levels and using both measures of activity. The association between physical health symptoms and SWL existed at the within-person level (self-report: $\gamma_{60}$ = -2.90, $p < .001$; directly-measured:

$\gamma_{60}$ = -3.51, $p < .001$), but not between-person (self-report: $\gamma_{06}$ = -2.67, $p$ = .44; directly-measured: $\gamma_{06}$ = -2.32 $p$ = .53), in both measures of PA.

# Discussion

The results presented here from a 14-day daily diary study employed self-report and direct-measures of (in)activity to further validate the within-person association between PA and SWL in emerging adults. In a series of increasingly complex models, the within-person association between PA and SWL was robust, even after accounting for SB, possible interactions between PA and SB, and plausible third variable influences.

## Physical Activity and Satisfaction with Life

This study added to the accumulating body of evidence that PA directly influences SWL through a within-person process (Maher et al., in press). Previous work investigating PA's influence on SWL in older adults has reported a positive between-person association between PA and SWL through PA's influence on affect, self-worth, self-efficacy, and mental health (Elavsky et al., 2005; Elavsky & McAuley, 2005; McAuley et al., 2008). This work has operated under the assumption that SWL is a stable construct and therefore that influences on SWL stem from static, between-person differences (i.e., more or less active people). Intensive sampling of SWL and health behaviors, in this study as well as previous work,  uncovered a within-person association between PA and SWL rather than a between-person association (Maher et al., in press). It may be that an association between PA and SWL is a within-person process and that the between-person association found by previous research was the manifestation of that within-person process over time in research designs that did not distinguish between within-person and between-person processes.

This work also tested the within-person association between PA and SWL using both self-reported and directly-measured activity. Given that the association between PA and SWL appeared to be the result of moderate-intensity PA (i.e., the association was significant using self-reported PA and trended toward significance using directly-measured PA), it was not surprising that both measures of activity were predictive of SWL. Although subject to criticism because of its emphasis on leisure-time PA and its tendency to disregard light-intensity PA that accrues as part of daily living, self-report measures of PA are able to capture moderate-intensity PA, which was the intensity activity most closely associated with SWL. Based on the results presented in this study, either measure of PA appears to be sufficient to determine associations between PA and SWL in emerging adults; however, this conclusion may not hold at later points in the adult lifespan as the amount of moderate- and vigorous-intensity PA declines further, light-intensity PA becomes even more prevalent, and light-intensity PA holds greater weight in an individual's ability to maintain normal functioning and independence (Miller, Rejeski, Reboussin, Ten Have, & Ettinger, 2000; Troiano et al., 2008; Wong, Wong, Pang, Azizah, & Dass, 2003).

One well-documented result of participation in moderate-intensity PA is improved well-being (Biddle & Mutrie, 2008; Bize, Johnson, & Plotnikoff, 2007; Penedo & Dahn, 2005). Studies have shown that moderate-intensity PA is associated with more positive self-perceptions and feeling states in adult populations (Biddle, 2000; Fox, 2000). Similar to other studies concerning PA and SWL, conclusions related to intensity-specific effects of activity have focused almost exclusively on the between-person association between intensity and well-being. These findings provide the first evidence of a within-person association between intensity-specific PA and SWL in emerging adults.

The significant within-person association between moderate-intensity PA and SWL revealed that people do not need to drastically change their overall levels of activity to enhance SWL. Rather than, for example, adopting a new, vigorous exercise program, people should find ways to incorporate short bouts of moderate-intensity PA into their daily lives so that they are merely engaging in more moderate-intensity PA than is typical for them. Moderate-intensity activities are those that range from 3.0-6.0 METs and include activities like brisk walking, household chores, and cycling for pleasure or transportation (Ainsworth et al., 1993, 2011). Replacing daily events like taking the elevator or escalator with taking the stairs, or parking in the furthest spot available instead of circling the lot looking for the closest parking spot represent viable ways to incorporate more moderate-intensity activity into daily living. Interventions aiming to increase PA, might find that targeting these types of moderate-intensity activities, may be a more manageable, less burdensome way to incorporate activity into emerging adult’s daily lives and still experience the positive benefits associated with being active. In fact, for the average person in this sample, integrating an additional 30 minutes of moderate-intensity activity on a given day would correspond to an increase in SWL that accounts for more than a quarter of the average decrease in SWL that typically occurs during  the eight-year span of emerging adulthood.

**Untangling the Association between Physical Activity, Sedentary Behavior, and Satisfaction with Life**

This study also teased apart the unique effects of PA and SB by differentiating low levels of activity from SB in self-report and direct measures of activity. Both PA and SB were associated with SWL at the within-person level. These findings suggest that PA and SB are additive influences on SWL.

The independent effects of SB on physical health, regardless of PA have been well-established (Healy et al., 2008, 2011; Katzmarzyk et al., 2009; Lynch, 2010; Teychenne et al., 2010; Thorp et al., 2011; van der Ploeg et al., 2012; van Uffelen et al., 2010); however, this is one of the first studies to document SB's negative association with a global indicator of well-being irrespective of PA (Depp et al., 2010; Frey et al., 2007). Given the deleterious acute physiological effects of excessive and prolonged SB (Bey & Hamilton, 2003; Hamilton et al., 1998; Zderic & Hamilton, 2006) and the well-founded association between chronic SB and harmful physiological and psychological consequences (Teychenne et al., 2010; Thorp et al., 2011), it is not surprising that SB detracts from SWL at the within-person level, even after accounting for PA levels. This finding illustrates the need for SWL-enhancing interventions to not only increase people's PA, but to also recognize SB as an important health-behavior change target and develop strategies to reduce the time people spend sitting (Gardiner, Eakin, Healy, & Owen, 2011; Owen, Bauman, & Brown, 2009; Owen, Healy, et al., 2010). Similar to strategies to incorporate more PA in people's lives, finding ways to reduce sitting time like standing while talking on the telephone or even interrupt sitting time by, for example, standing during TV commercials may represent manageable daily changes people can make to enhance their SWL. Indeed, findings from this study indicate that for the average person in our sample, reducing SB for approximately 30 minutes on a given day would correspond to an increase in SWL that counteracts more than a quarter of the decrease in SWL that occur during emerging adulthood.

But perhaps the most efficient way to enhance SWL in emerging adults, as indicated by findings from this study, is to displace SB with moderate-intensity PA. SB and PA are incompatible health behaviors (Marshall & Ramirez, 2011; Owen, Healy, et al., 2010; Pate et al., 2008). Therefore, reductions in SB will lead to an increase in some form of PA (Epstein, Saelens,

& O’Brien, 1995). The aforementioned opportunities to reduce sitting time (e.g., standing while on the telephone or standing during TV commercials) displace SB with light-intensity PA; however there are also many opportunities to incorporate moderate-intensity PA into once sedentary activities. For example, riding a bicycle to work or school as opposed to driving or taking the bus, or even washing your car manually instead of taking it to the car wash  are both ways to incorporate moderate-intensity PA into daily living (Ainsworth et al., 1993, 2011), while simultaneously limiting SB. It may be that targeting the displacement of SB with moderate-intensity PA provides individuals with the most effective way to enhance SWL as findings from this work indicated that for the average person in our sample, replacing SB for approximately 30 minutes on a given day with moderate-intensity PA corresponds to an increase in SWL equivalent to almost three-quarters of the drop in SWL that occur during the eight year span of emerging adulthood.

To further evaluate the effects of PA and SB on SWL, the potential interaction between daily PA and daily SB as well as the potential interaction between daily PA and overall SB on SWL were explored. The null findings concerning the interactive effects of PA and SB indicated that the effect of each health behavior on SWL was not dependent upon the level of the other health behavior. These null findings emphasize the importance of targeting both types of health behaviors. While targeting one particular health behavior would be an effective means to enhance SWL, ultimately the simultaneous implementation of strategies to manipulate both health behaviors, through the displacement of SB with moderate-intensity PA, would provide the greatest chance to increase SWL.

**Direction of the Associations between Physical Activity, Sedentary Behavior, and Satisfaction with Life**

Although the conclusions that can be drawn from this study are limited due to a lack of experimental data, alternative causal pathways were evaluated to strengthen the conclusions of this work. Previous day's SWL was not predictive of subsequent day's PA at the between- or within-person level. This finding is consistent with work by Maher et al. (in press) who found previous day's SWL was not associated with subsequent day's self-reported PA in two daily diary studies of emerging adults lasting 8 and 14 days. Even though results related to the sequential influence of PA on SWL appear to be consistent, experimental work will be a crucial next step to better understanding the causal influence of PA on SWL.

To the best of our knowledge, this is the first study to examine the alternative causal pathway of SB and SWL. Results from self-reported SB revealed that previous day's SWL was predictive of subsequent day's SB at the within-person level; however, this association was not found when examining directly-measured SB. Given that results from the alternative casual sequence were mixed, it is unclear whether SB influences SWL or SWL influences SB. SB could reduce SWL because SB adversely effects physiological and psychological factors that may ultimately detract from SWL (e.g., increased risk for premature death and metabolic syndromes and decreased glucose tolerance and mental health). Conversely, SWL may influence SB. Low SWL may lead to poor mental health and greater depressive symptoms, which are associated with more sedentary time and feelings of lethargy (Elliot, Kennedy, Morgan, Anderson, & Morris, 2012). In samples of emerging adults, negative associations have been found between SWL and depressive symptoms and feelings of anxiety (Samaranayake & Fernando, 2011). Previous research on older adults and adolescents has also indicated bidirectional pathways between depressive symptoms and SB (operationalized as a combination of frequency of inactivity and low levels of PA; Lindwall, Larsman, & Hagger, 2011; Stavrakakis, de Jonge, Ormel, & Oldehinkel, 2012). Further research is needed to draw more precise conclusions related to the causal sequence between SB and SWL.

**Other Influences on Satisfaction with Life**

It is not surprising that both mental and physical health symptoms were negatively related to SWL. Findings from this study confirm the established top-down, between-person negative association between mental health symptoms and SWL (Diener et al., 1985; McAuley et al., 2006) and add to the accumulating body of evidence that daily variation in mental health symptoms are negatively associated with SWL (Maher et al., in press). Mental health symptoms can hamper relevant goal pursuits and these pursuits serve as a major contributor to SWL, thus mental health symptoms adversely impact SWL.

Although physical health status has been linked with SWL through top-down processes in previous work (McAuley et al., 2006), this is the first study to indicate that physical health symptoms are associated with SWL by way of a bottom-up, within-person process and not a top-down, between-person process. Physical health symptoms often hinder a person's ability to function normally, and even independently, within society (McAuley et al., 2006; Motl & McAuley, 2010). The consequences associated with being unable to function normally within society can have implications for goal pursuit and ultimately SWL. In fact, the effect of physical health symptoms may be even more relevant in populations where physical health symptoms accrue as a result of age-related decline (i.e., older adulthood).

Additionally, mental and physical health may serve as potential moderators of the association between PA and SWL. Our sample was relatively healthy, mentally and physically speaking, so examining the moderating effects of these two indicators of health on the PA-SWL association would be inappropriate. Investigating the effects of mental and physical health as moderators on the association between daily PA and SWL in samples where mental or physical health symptoms are more diverse could shed further light on the beneficial effects of daily PA in special populations and is an important direction for future research.

**Limitations**

This study was not without limitations. Although emerging adulthood appears to be a pivotal point in examining the influences on SWL, as a result of its sharp decrease during this time, the sample used in this study represents a select sample of emerging adults. Our sample was fairly homogenous with respect to race, education, and physical abilities. It is currently unknown whether PA and SB have similar associations with other samples of emerging adults. Many emerging adults forgo college and this "Forgotten Half" of emerging adults may differ from college students in the factors that influence SWL (William T. Grant Foundation Commission on Work, Family, and Citizenship, 1988). Furthermore, the association between health behaviors and SWL present in emerging adults may differ at other points in the adult lifespan. For example, Heckhausen and colleagues (2010) noted that as individuals age, their motives and goals change. While self-reported moderate-intensity PA is associated with SWL in this study of emerging adults, one might speculate that the intensity-specific effects of PA on SWL may be a function of age and health status. For example, older adults motivated to maintain their functional abilities, and ultimately their independence, may experience improved well-being as a result of engaging in light-intensity PA as opposed to moderate-intensity PA. Research on diverse populations would provide valuable insight concerning the influence of health behaviors on SWL across the adult lifespan.

With respect to measurement issues, this study used self- report and direct measures of (in)activity. Self-report measures of activity tend to overestimate the amount of time people spend engaging in PA compared to direct measures (Adamo et al., 2009; Prince et al., 2008); however, because this study adjusted for valid hours, directly-measured PA may actually underestimate PA. Self-report measures of PA are subject to recall bias and direct measures of PA are dependent upon participant compliance (Haskell, 2012; Tudor-Locke & Myers, 2001). Notwithstanding these limitations, we are confident in conclusions from this study because of the consistency of results across both measures of activity.

In this study, directly-measured SB was operationalized as < 100 counts·min$^{-1}$ as defined by Freedson et al. (1998). There is currently debate as to what the best cut-off point is for measuring SB. A range of counts have been used in previous research to define SB, ranging from as little as < 50 counts·min$^{-1}$ to as much as < 250 counts·min$^{-1}$ (Kozey-Keadle et al., 2011); however recent findings have indicated that the < 100 counts·min$^{-1}$ criteria for SB is equivalent in terms of sensitivity and specificity to dual accelerometers/inclinometers in capturing SB (Kozey-Keadle, Libertine, Staudenmayer, & Freedson, 2012). It should also be noted that accelerometers in this study cannot distinguish time spent sitting from other stationary activities.

As previously mentioned, because this study is observational in nature, it is impossible to draw conclusions related to causality. This study, did however, strengthen findings as to the direction of the association between PA and SWL and SB and SWL, by examining an alternative temporal sequence. We also controlled for several plausible third variables that might account for the relation between health behaviors and SWL to strengthen conclusions, although several possible mechanisms remain unexplored (e.g., perceived control, self-efficacy). Ultimately, experimental work is needed to determine the causal role that PA and SB play on changes in SWL.

**Summary of Conclusions**

This study extended knowledge concerning the within-person association between two health behaviors and SWL in emerging adults. Findings indicated that PA and SB have additive, within-person effects on SWL using both self-report and direct measures of (in)activity. Furthermore, it appears that daily moderate-intensity PA may drive the association between PA and SWL. Understanding the role that PA and SB play in influencing daily SWL is especially relevant during emerging adulthood because SWL decreases more during those years than any other period in the lifespan and, the transition into this phase is accompanied by distinct changes in people's PA and SB. These findings not only illustrate the importance of increasing daily moderate- intensity PA but also introduce the novel idea of reducing daily SB as a way to enhance SWL.

# CHAPTER 3: CONCLUSION

The present study revealed the influential role that daily variation in two health behaviors, physical activity (PA) and sedentary behavior (SB), have on satisfaction with life (SWL) during emerging adulthood. Specifically, this study demonstrated that (1) the within-person association between PA and SWL was evident in both self-reported and directly-measured PA, (2) SB also was associated with SWL at the within-person level using both measures of behavior, indicating that these health behaviors have additive effects on SWL, (3) daily variation in moderate-intensity PA appears to drive the association between PA and SWL, and (4) the within-person association between these two health behaviors and SWL was robust even after controlling for plausible third variables in emerging adults. Ultimately, this study allowed more precise conclusions to be drawn about the nature of the association between health behaviors (i.e., PA and SB) and SWL.

The eight-year span between the ages of 18 and 25 is a challenging time for many emerging adults. During this time emerging adults experience newly found independence, while remaining tethered to parents in some ways, and explore a variety of opportunities related to love, work, and worldviews, essentially going through a series of trials and errors (Arnett, 1998, 2000). Coinciding with the uncertainty that is pervasive throughout emerging adulthood, emerging adults also experience important psychological changes during this developmental period. Longitudinal studies have shown a high level of affective lability during emerging adulthood (Röcke, Li, & Smith, 2009). Meanwhile, cross-sectional studies have demonstrated differences in self-evaluative and attributional tendencies from the beginning to end of this developmental period (Orth, Robins, & Soto, 2010; Robins, Trzesniewski, Tracy, Gosling, & Potter, 2002). Together these studies suggest that emerging adulthood is particularly taxing and can exert a toll on people’s well-being. Given these changes it is not surprising that from ages 18 to 25, SWL appears to decrease more sharply than at any other point in the adult lifespan (Stone et al., 2010).

In a sense, the trials and tribulations of emerging adulthood represent a series of highs and lows that could either add to or detract from SWL, respectively. In this sample, psychological highs may have stemmed from deciding upon a major, connecting with friends, or even feeling a part of a group. Conversely, psychological lows may have been the result of receiving a poor grade on a quiz or exam, feuding with friends, or being excluded from a group. These lows have the potential to occur on a daily basis. Additionally, throughout emerging adulthood not only do overall levels of PA and SB change (Matthews et al., 2008; Troiano et al., 2008), but specific events and constraints associated with emerging adulthood (e.g., class/work schedules, extracurricular activities, and social calendar) may result in changes in daily PA and SB (Behrens & Dinger, 2003, 2005; Conroy et al., 2011; Sisson et al., 2008). Results from this study have provided insights regarding ways to combat the daily lows that occur during emerging adulthood with changes in daily health behaviors.

The direct within-person association between health behaviors (i.e., PA and SB) and SWL documented in this study has important implications for well-being research and for developing strategies to enhance well-being in emerging adulthood. Maher et al. (in press) found a direct within-person association between PA and SWL in emerging adults using self-reported PA. This study extended previous work by differentiating between low levels of activity and inactivity (i.e., SB) and determining each health behavior's association with SWL using self-report and direct measures of (in)activity. Furthermore, the additive effects of daily PA and SB on SWL found in this study indicated that strategies to enhance SWL are not constrained exclusively to increasing daily PA.

Although the additive effects of PA and SB are well-documented in terms of their effect on physiological outcomes (Healy et al., 2008, 2011; Katzmarzyk et al., 2009; Lynch, 2010; Thorp et al., 2011; van der Ploeg et al., 2012; van Uffelen et al., 2010), this study was the first to differentiate the effects of these two health behaviors in relation to SWL. By differentiating the effects of PA from SB the results from this study add important insights to the emerging literature concerning the adverse impact of SB on well-being. Other studies have shown similar findings concerning the negative impact of SB on indicators of well-being. In a recent review of cross-sectional and prospective studies Teychenne, Ball & Salmon (2010) found that engaging in greater amounts of overall sedentary time as well as sedentary activities (e.g., TV viewing, computer use) was associated with a greater risk for depressive symptoms. Work by Sanchez-Villegas et al. (2008) has echoed this same sentiment. In a 6-year prospective study of over 10,000 adults, Sanchez-Villegas et al. (2008) found that individuals who engaged in sedentary activities (i.e., TV viewing and/or computer use) for more than forty-two hours per week were thirty-one percent more likely to suffer from feelings of depression, anxiety, and stress compared to those spending less than 10.5 hours per week engaging in sedentary activities. Findings from this study complimented previous findings that document the deleterious effect of SB on well-being. Importantly, these results have indicated that for those interested in enhancing SWL, and ultimately well-being, strategies should not only target increasing PA, but strategies should also focus on limiting or interrupting SB.

Findings from this work also revealed that changes in these daily health behaviors do not have to be drastic changes to overall levels PA and SB; rather short, manageable bouts of activity can be incorporated into daily living as a way to acutely increase PA and limit or interrupt SB. Moderate-intensity PA, which encompasses a wide variety of activities ranging from brisk walking to household chores to cycling for pleasure or transportation and typically expends between 3.0 and 6.0 metabolic equivalent units (Ainsworth et al., 1993, 2011), has long been recognized as a valuable form of activity to gain mental and physical health benefits (Haskell et al., 2007; Pate et al., 1995; Physical Activity Guidelines Advisory Committee, 2008). This work suggested that by incorporating just 30 minutes of moderate-intensity PA in the context of daily living on a given day could combat more than a quarter of the sharp decline in SWL that occurs during the challenging time of emerging adulthood. Moreover, although this 30 minutes can be a product of moderate-intensity PA that results from a work out at the gym, it does not have to be. An equivalent psychological effect can also be derived from 30 minutes of activity incorporated into daily life through the reduction of SB.

Indeed, many activities that are typically completed in a seated or reclined position serve as opportunities to incorporate activity into daily life (Epstein et al., 1995). For example, replacing daily events like driving to work with bicycling or walking to work, or washing your car manually instead of going to the car wash, represent viable ways to incorporate moderate-intensity activity into daily living, while simultaneously reducing SB. In fact, compared to the effect of only targeting one health behavior (i.e., either increasing moderate-intensity PA or reducing SB), results from this study suggested that displacing SB with moderate-intensity PA for as little as 30 minutes on a given day would correspond to an increase in SWL three times the amount that would result from targeting a single health behavior.

Although this study proposed manageable changes in daily health behaviors as an effective way to enhance SWL, it is currently unclear if similar changes in daily health behaviors have an analogous impact on well-being across other points of the adult lifespan. Heckhausen and colleagues (2010) postulated that as individuals age, their motives and goals change. While self-reported moderate-intensity PA appears to be driving the PA-SWL association in this study of emerging adults, one might speculate that the intensity-specific effects of PA on SWL may be a function of age. For example, older adults striving to maintain their functional abilities, and ultimately their independence, may experience improved well-being as a result of engaging in light-intensity PA (i.e., less than 3.0 METs; Keysor, 2003; McAuley et al., 2006; Miller et al., 2000; Seeman & Chen, 2002) as opposed to moderate-intensity PA. Indeed, recent studies have indicated light-intensity PA (e.g., walking) is associated with improved mental and physical health in older adults (Diehr & Hirsch, 2010; Peterson, Rhea, Sen, & Gordon, 2010; Warburton et al., 2006; Wong et al., 2003). Future research is needed to determine how daily health behaviors, of varying intensities, impact SWL at different points throughout the adult lifespan.

Furthermore, this work suggests that daily changes in health behaviors (i.e., PA and SB) are viable ways to enhance SWL; however, it is unclear how chronic changes in daily PA and SB impact the within-person association between these health behaviors and SWL. Over time, chronic changes in daily PA and SB at the within-person level may create a between-person association with SWL. Longitudinal observational and experimental work is needed to better understand how changes in health behaviors accumulate over time and ultimately affect SWL.

This study has contributed to our understanding of the within-person association between two health behaviors and SWL. Although further work is necessary to better understand the nature of the association between these health behaviors and SWL beyond emerging adulthood, this study provided insight into potential strategies to enhance SWL during emerging adulthood. Ultimately, daily changes in moderate-intensity PA and SB provide manageable ways to incorporate activity into daily living and a means to counteract the steep decline in SWL that usually occurs during the challenging stage of emerging adulthood.

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# APPENDIX

Table 1

*Descriptive Statistics, Intraclass Correlations, and Correlations between Satisfaction with Life, Physical Activity, Sedentary Behavior, and Mental and Physical Health Symptoms*

| | *M* | *SD* | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Satisfaction with Life | 75.56 | 20.11 | (.42) | .08 | .03 | -.05 | .05 | -.66 | -.61 |
| 2. Physical Activity (Self-Report) | 648.88 | 504.65 | .15 | (.47) | .27 | -.27 | -.37 | .03 | -.07 |
| 3. Physical Activity (Accelerometer) | 28,488.29 | 13,892.24 | .15 | .42 | (.30) | -.20 | -.59 | -.02 | -.17 |
| 4. Sedentary Behavior (Self-Report) | 365.46 | 154.45 | -.13 | -.31 | -.26 | (.48) | .25 | .04 | .17 |
| 5. Sedentary Behavior (Accelerometer) | 66.92 | 8.45 | -.11 | -.38 | -.57 | .33 | (.28) | -.09 | .01 |
| 6. Mental Health Symptoms | 2.54 | 1.50 | -.52 | -.04 | -.08 | .07 | .04 | (.42) | .85 |
| 7. Physical Health Symptoms | 2.96 | 1.78 | -.44 | -.18 | -.25 | .18 | .14 | .69 | (.40) |

*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. Coefficients above the diagonal represent correlations of intraindividual means. Descriptive statistics were calculated using raw data. Correlations were calculated using transformed scores. *M* = sample-level mean, *SD* = sample-level standard deviation.

Table 2

*Intraindividual Covariation in Physical Activity Predicting Daily Satisfaction with Life Using Self-Report and Direct Measures of Activity*

| | Self-Reported Behavior | Directly-Measured Behavior |
|---|---|---|
| | Parameter Estimate (Standard Error) | Parameter Estimate (Standard Error) |
| Fixed Effects | | |
| Intercept, $\gamma_{00}$ | 75.40* (1.21) | 75.59* (1.27) |
| Overall Physical Activity, $\gamma_{01}$ | 0.22 (0.32) | -0.02 (0.20) |
| Daily Physical Activity, $\gamma_{10}$ | 0.80* (0.13) | 0.38* (0.06) |
| Random Effects | | |
| Variance Intercept, $u_0$ | 175.13* (24.17) | 184.07* (26.34) |
| Variance Physical Activity, $u_1$ | 0.94* (0.29) | 0.13* (0.05) |
| Residual | 212.65 | 206.28 |
| *-2LL* | 13957.3 | 11626.4 |
| *AIC* | 13965.3 | 11634.4 |

*Note.* Unstandardized estimates and standard errors. Model is based on 14 occasions nested within 128 participants for a total of 1643 (self-report) and 1384 (directly-measured) observations. Transformed scores were used to estimate parameters. *AIC* = Akaike Information Criterion. *-2LL* = -2 Log Likelihood. $*p < .05$.

Table 3

*Intraindividual Covariation in Physical Activity and Sedentary Behavior Predicting Daily Satisfaction with Life Using Self-Report and Direct Measures of (In)Activity*

| | Self-Reported Behavior | Directly-Measured Behavior |
|---|---|---|
| | Parameter Estimate (Standard Error) | Parameter Estimate (Standard Error) |
| Fixed Effects | | |
| Intercept, $\gamma_{00}$ | 75.29* (1.23) | 75.56* (1.27) |
| Overall Physical Activity, $\gamma_{01}$ | 0.25 (0.34) | 0.11 (0.25) |
| Daily Physical Activity, $\gamma_{10}$ | 0.57* (0.13) | 0.22* (0.07) |
| Overall Sedentary Behavior, $\gamma_{02}$ | 0.03 (0.11) | 0.01 (0.01) |
| Daily Sedentary Behavior, $\gamma_{20}$ | -0.21* (0.05) | -0.005* (0.001) |
| Random Effects | | |
| Variance Intercept, $u_0$ | 177.26* (24.51) | 183.00* (26.32) |
| Variance Physical Activity, $u_1$ | 0.67* (0.27) | 0.15* (0.05) |
| Variance Sedentary Behavior, $u_2$ | 0.11* (0.04) | |
| Residual | 198.39 | 201.45 |
| *-2LL* | 13793.3 | 11623.3 |
| *AIC* | 13807.3 | 11631.3 |

*Note.* Unstandardized estimates and standard errors. Model is based on 14 occasions nested within 128 participants for a total of 1643 (self-report) and 1384 (directly-measured) observations. Transformed scores were used to estimate parameters. *AIC* = Akaike Information Criterion. *-2LL* = -2 Log Likelihood. *$p$ < .05.

Table 4

*Intraindividual Covariation in Physical Activity, Sedentary Behavior, and an Interaction between Physical Activity and Sedentary Behavior Predicting Daily Satisfaction with Life Using Self-Report and Direct Measures of (In)Activity*

| | Self-Reported Behavior | Directly-Measured Behavior |
|---|---|---|
| | Parameter Estimate (Standard Error) | Parameter Estimate (Standard Error) |
| Fixed Effects | | |
| Intercept, $\gamma_{00}$ | 75.34* (1.23) | 75.50* (1.29) |
| Overall Physical Activity, $\gamma_{01}$ | 0.25 (0.34) | 0.11 (0.25) |
| Daily Physical Activity, $\gamma_{10}$ | 0.56* (0.13) | 0.22* (0.07) |
| Overall Sedentary Behavior, $\gamma_{02}$ | 0.01 (0.12) | 0.01 (0.01) |
| Daily Sedentary Behavior, $\gamma_{20}$ | -0.21* (0.05) | -0.005* (0.001) |
| Daily Physical Activity x Overall Sedentary Behavior, $\gamma_{11}$ | 0.01 (0.01) | -0.01 (0.01) |
| Daily Physical Activity x Daily Sedentary Behavior, $\gamma_{30}$ | 0.01 (0.01) | -0.01 (0.01) |
| Random Effects | | |
| Variance Intercept, $u_0$ | 177.12* (24.49) | 182.93* (26.34) |
| Variance Physical Activity, $u_1$ | 0.67* (0.28) | 0.15* (0.05) |
| Variance Sedentary Behavior, $u_2$ | 0.11* (0.04) | |
| Residual | 198.54 | 201.61 |
| *-2LL* | 13807.7 | 11655.4 |
| *AIC* | 13821.7 | 11663.4 |

*Note.* Unstandardized estimates and standard errors. Model is based on 14 occasions nested within 128 participants for a total of 1643 (self-report) and 1384 (directly-measured) observations. Transformed scores were used to estimate parameters. *AIC* = Akaike Information Criterion. *-2LL* = -2 Log Likelihood. $*p < .05$.

Table 5
*Intraindividual Covariation in Physical Activity, Sedentary Behavior, Mental Health Symptoms, Physical Health Symptoms, and an Interaction between Physical Activity and Sedentary Behavior Predicting Daily Satisfaction with Life Using Self-Report and Direct Measures of (In)Activity*

| | Self-Reported Behavior | Directly-Measured Behavior |
|---|---|---|
| | Parameter Estimate (Standard Error) | Parameter Estimate (Standard Error) |
| Fixed Effects | | |
| Intercept, $\gamma_{00}$ | 76.61* (1.43) | 77.80* (1.55) |
| Overall Physical Activity, $\gamma_{01}$ | 0.19 (0.24) | -0.08 (0.18) |
| Daily Physical Activity, $\gamma_{10}$ | 0.35* (0.12) | 0.14* (0.07) |
| Overall Sedentary Behavior, $\gamma_{02}$ | 0.04 (0.09) | -0.01 (0.01) |
| Daily Sedentary Behavior, $\gamma_{20}$ | -0.12* (0.04) | -0.003* (0.001) |
| Daily Physical Activity x Overall Sedentary Behavior, $\gamma_{11}$ | -0.01 (0.01) | -0.01 (0.01) |
| Daily Physical Activity x Daily Sedentary Behavior, $\gamma_{30}$ | 0.01 (0.01) | -0.01 (0.01) |
| Overall Mental Health Symptoms, $\gamma_{04}$ | -17.24* (3.93) | -21.51* (4.12) |
| Daily Mental Health Symptoms, $\gamma_{40}$ | -12.46* (1.49) | -13.04* (1.56) |
| Overall Physical Health Symptoms, $\gamma_{05}$ | -5.25 (3.26) | -1.30 (3.38) |
| Daily Physical Health Symptoms, $\gamma_{50}$ | -3.16* (0.91) | -2.81* (0.95) |
| Monday, $\gamma_{60}$ | -0.78 (1.23) | -0.52 (1.39) |
| Tuesday, $\gamma_{70}$ | -1.86 (1.16) | -1.99 (1.23) |
| Wednesday, $\gamma_{80}$ | 0.31 (1.17) | 0.08 (1.26) |
| Friday, $\gamma_{90}$ | -1.61 (1.20) | -0.69 (1.33) |
| Saturday $\gamma_{10,0}$ | 0.13 (1.25) | -0.40 (1.36) |
| Sunday $\gamma_{11,0}$ | -0.88 (1.27) | -0.76 (1.40) |
| Day in Study, $\gamma_{12,0}$ | -0.06 (0.09) | -0.21* (0.10) |
| Random Effects | | |
| Variance Intercept, $u_0$ | 95.12* (13.73) | 100.52* (15.38) |
| Variance Physical Activity, $u_1$ | 0.68* (0.25) | 0.07* (0.03) |
| Variance Sedentary Behavior, $u_2$ | 0.04* (0.03) | |
| Variance Mental Health Symptoms, $u_4$ | 115.19* (33.09) | 113.41* (36.89) |
| Variance Physical Health Symptoms, $u_5$ | 16.46 (11.98) | 15.15 (12.74) |
| Residual | 153.98 | 152.78 |
| *-2LL* | 13393.9 | 11272.3 |
| *AIC* | 13425.9 | 11294.3 |

*Note.* Unstandardized estimates and standard errors. Model is based on 14 occasions nested within 128 participants for a total of 1643 (self-report) and 1384 (directly-measured) observations. Transformed scores were used to estimate parameters. *AIC* = Akaike Information Criterion. *-2LL* = -2 Log Likelihood. *$p < .05$.

Table 6

*Multivariate Multilevel Model of Lagged Satisfaction with Life Predicting Daily Physical Activity and Sedentary Behavior Using Self-Report and Direct Measures of (In)Activity*

| | Self-Reported Behavior | Directly-Measured Behavior |
|---|---|---|
| | Parameter Estimate (Standard Error) | Parameter Estimate (Standard Error) |
| Predicting Physical Activity | | |
| Fixed Effects | | |
| Intercept, $\gamma_{00}$ | 18.49* (0.32) | 40.27* (0.45) |
| Overall Satisfaction with Life, $\gamma_{01}$ | 0.03 (0.02) | 0.02 (0.04) |
| Previous Day's Satisfaction with Life, $\gamma_{10}$ | 0.01 (0.01) | 0.01 (0.02) |
| Random Effects | | |
| Previous Day's Satisfaction with Life, $u_1$ | 17.98* | 91.09* |
| Predicting Sedentary Behavior | | |
| Fixed Effects | | |
| Intercept, $\gamma_{00}$ | 54.97* (0.93) | 66.09* (0.54) |
| Overall Satisfaction with Life, $\gamma_{02}$ | -0.04 (0.07) | 0.02 (0.03) |
| Previous Day's Satisfaction with Life, $\gamma_{20}$ | -0.04* (0.02) | 0.01 (0.02) |
| Random Effects | | |
| Previous Day's Satisfaction with Life, $u_2$ | 110.11* | 51.22* |

*Note.* Unstandardized estimates and standard errors. Model is based on 13 occasions nested within 128 participants for a total of 1519 (self-report) and 1324 (directly-measured) observations. Transformed scores were used to estimate parameters. *$p < .05$.

Table 7

*Intraindividual Covariation in Physical Activity by Intensity, Sedentary Behavior, and an Interaction between Physical Activity and Sedentary Behavior Predicting Daily Satisfaction with Life Using Self-Report and Direct Measures of (In)Activity*

| | Self-Reported Behavior | Directly-Measured Behavior |
|---|---|---|
| | Parameter Estimate (Standard Error) | Parameter Estimate (Standard Error) |
| Fixed Effects | | |
| Intercept, $\gamma_{00}$ | 76.60* (1.43) | 77.57* (3.02) |
| Overall Vigorous Physical Activity, $\gamma_{01}$ | 12.11 (7.36) | -0.21 (2.26) |
| Daily Vigorous Physical Activity, $\gamma_{10}$ | 3.49 (2.10) | -0.29 (0.65) |
| Overall Moderate Physical Activity, $\gamma_{02}$ | -0.28 (0.78) | 1.00 (1.35) |
| Daily Moderate Physical Activity, $\gamma_{20}$ | 0.64* (0.28) | 0.61[†] (0.33) |
| Overall Walking, $\gamma_{03}$ | 0.24 (0.39) | |
| Daily Walking, $\gamma_{30}$ | 0.26 (0.16) | |
| Overall Sedentary Behavior, $\gamma_{04}$ | 0.09 (0.09) | 0.01 (0.01) |
| Daily Sedentary Behavior, $\gamma_{40}$ | -0.12* (0.04) | -0.003* (0.0009) |
| Overall Mental Health Symptoms, $\gamma_{05}$ | -19.29* (4.16) | -19.99* (4.52) |
| Daily Mental Health Symptoms, $\gamma_{50}$ | -12.96* (1.51) | -12.88* (1.57) |
| Overall Physical Health Symptoms, $\gamma_{06}$ | -2.68 (3.45) | -2.33 (3.71) |
| Daily Physical Health Symptoms, $\gamma_{60}$ | -2.91* (0.85) | -3.51* (1.03) |
| Monday, $\gamma_{70}$ | -0.91 (1.23) | -0.58 (1.40) |
| Tuesday, $\gamma_{8,0}$ | -1.94 (1.16) | -1.93 (1.25) |
| Wednesday, $\gamma_{90}$ | 0.13 (1.18) | 0.24 (1.27) |
| Friday, $\gamma_{10,0}$ | -2.15 (1.22) | -0.55 (1.34) |
| Saturday $\gamma_{11,0}$ | 0.38 (1.25) | -0.12 (1.38) |
| Sunday $\gamma_{12,0}$ | -1.12 (1.27) | -0.71 (1.42) |
| Day in Study, $\gamma_{13,0}$ | -0.05 (0.09) | -0.20* (0.09) |
| Random Effects | | |
| Variance Intercept, $u_0$ | 94.84* (13.91) | 100.00* (15.40) |
| Variance Vigorous Physical Activity, $u_1$ | 92.85 (68.94) | |
| Variance Moderate Physical Activity, $u_2$ | 3.82* (1.48) | |
| Variance Mental Health Symptoms, $u_5$ | 122.88* (34.81) | 111.27* (37.81) |
| Variance Physical Health Symptoms, $u_6$ | 4.56 (10.80) | 30.99* (14.01) |
| Residual | 155.12 | 156.62 |
| *-2LL* | 13369.3 | 11274.9 |
| *AIC* | 13401.3 | 11288.9 |

*Note.* Unstandardized estimates and standard errors. Model is based on 14 occasions nested within 128 participants for a total of 1643 (self-report) and 1384 (directly-measured) observations. Transformed scores were used to estimate parameters. *AIC* = Akaike Information Criterion. *-2LL* = -2 Log Likelihood. *$p < .05$, [†]$p < .07$.

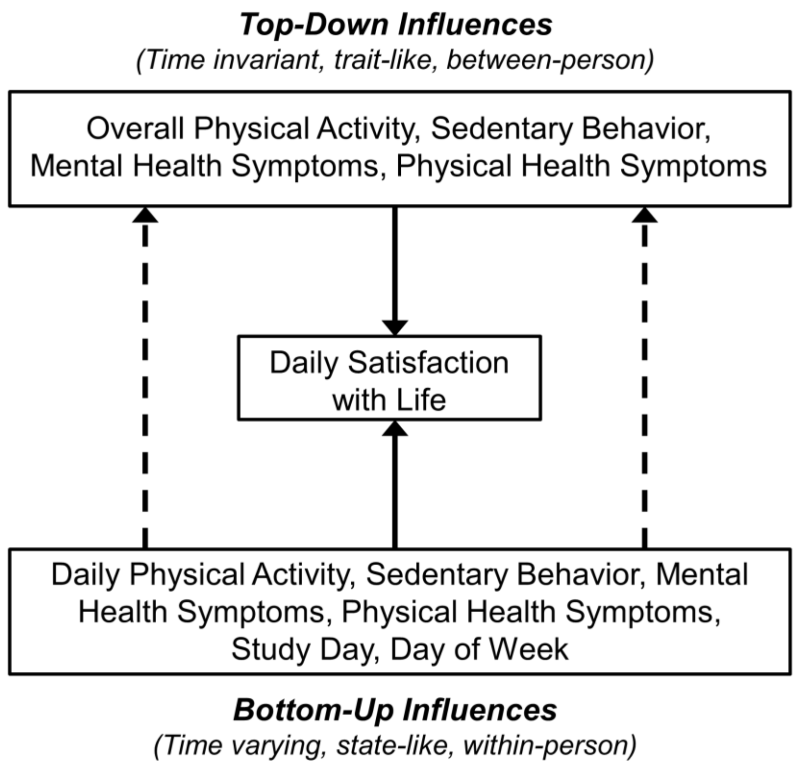


Figure 1. A conceptual representation of top-down and bottom-up influences on SWL (adapted from Maher et al., in press). Top-down and bottom-up influences can both directly influence SWL. Dashed arrows indicate that daily behaviors and experiences (i.e., bottom-up influences) may accumulate over time (e.g., repeated measures data), ultimately influencing overall tendencies or dispositions (i.e., top-down influences).