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The Trajectory of Sedentary Behavior from Adolescence to Emerging Adulthood

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THE TRAJECTORY OF SEDENTARY BEHAVIOR FROM ADOLESCENCE TO EMERGING ADULTHOOD

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US adolescents spend up to 8 hours daily in screen time. Efforts to reduce sedentary time have often focused on identifying its correlates. However, little is known about the trajectory of adolescents' screen time or factors that predict it. This study examined change in screen time from age 13 to 23 and its predictors in a representative US sample. Adolescents (N = 3,705; 46.3% boys) from the National Longitudinal Study of Adolescent to Adult Health's public-use data self-reported their screen time (hours/week watching TV and videos, and playing video/computer games) in 1994, 1996, 2001 and 2008. Piecewise latent growth models within a cohort-sequential design modelled screen time from ages 13-18 and 19-23 years. Predictors of change for each piece of the model were gender, parental education and limits on screen time, household income, perception of neighborhood safety, race/ethnicity, BMI, physical activity (PA) and employment status. Results indicated that adolescents spent an average of 24.99 hours/week in screen time at age 13 and > 14 hours/week until age 23. Screen time decreased 1.27 hours per week per year from age 13 to 18 then increased .39 hours per week per year from age 19 to 23 (ps < .001). From 13 to 18, decrease in screen time was associated with feeling safe in the one's neighborhood (b = 2.70, p = .01), having parental

limits on screen time (b = 1.22, $p = .02$), and being Asian American (vs. whites; b = 2.27, $p = .02$). From 19 to 23, African Americans (b = -1.13, $p < .001$) and Asian Americans (b = .67, $p = .04$) had a lower increase compared to whites. More bouts of PA were also associated with lower increase in screen time (b = -.04, $p = .03$) during emerging adulthood. Participants who were only in school (b = .43, $p = .01$) or neither in school nor working (b = .91, $p < .001$) had a greater increase in screen time than those who were only working. Interestingly, screen time increased after the age of 18, a point when many transitions, such as the entry into college, often occur. However, given the high levels of screen time maintained from ages 13 to 23, effective means of curbing screen time during these developmental periods are needed. Focusing on modifiable factors such as parental limits on screen time and physical activity may help to curb this behavior. Since the factors associated with change in screen time from ages 13-18 and 19-23 differed, this may be important to consider when developing interventions to reduce sedentary behavior.

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Chapter 1 – Introduction

Over the past few decades, there has been an increase in adolescents' engagement in sedentary activities, such as watching television and playing computer games (Pate, Mitchell, Byun, & Dowda, 2011). This increase has paralleled the rising rates of obesity and is a critical factor underlying the obesity epidemic (Pate et al., 2011). In fact, studies of both children and adults show that greater time spent in sedentary activities is associated with an increased risk of obesity (Mitchell, Rodriguez, Schmitz, & Audrain-McGovern, 2013; Thorp, Owen, Neuhaus, & Dunstan, 2011). Accumulating evidence linking sedentary behavior to other health conditions also underscores the importance of curbing sedentary time. In particular, studies demonstrate that high levels of sedentary behavior are associated with an elevated risk of diabetes (Grøntved & Hu, 2011), cardiovascular disease related mortality, and all-cause mortality in adults, independent of physical activity and body mass index (BMI; Thorp et al., 2011).

These findings are of concern, especially since many adolescents exceed the current recommendations of no more than 2 hours a day of screen time (Pediatrics, 2001). Specifically, recent studies indicate that youth on average spend up to 3 or more hours daily watching television, and may engage in 5.5 to 8.5 hours of sedentary activities every day outside of school (Pate et al., 2011; Salmon, Tremblay, Marshall, & Hume, 2011). Because adolescence is a critical period for developing health habits that may continue into adulthood (Mamun, O'Callaghan, Williams, & Najman, 2012), such high levels of sedentary behavior have stimulated efforts to reduce adolescents' sedentary time. Research pursuits in this area have often focused on the correlates of sedentary behavior, such as BMI, race/ethnicity, and physical activity (Pate et al., 2011), and provide some insight into factors to consider when developing interventions (Norman, Schmid, Sallis, Calfas, & Patrick, 2005; Van der Horst, Paw, Twisk, & Van Mechelen, 2007).

However, the trajectory of sedentary behavior from adolescence to emerging adulthood (ages 18 to 25) and factors that predict the trajectory have received far less attention. These topics are important to consider since they may help identify those who experience increases in sedentary behavior as adults and have an increased risk for adverse health outcomes. As such, research examining the trajectory of sedentary behavior in adolescents may prove beneficial in identifying candidates that could benefit from interventions that aim to reduce sedentary time.

The available evidence from prospective and cross-sectional studies suggest that sedentary behavior differs between boys and girls (Pate et al., 2011; Van der Horst et al., 2007) and may increase (Basterfield et al., 2011; Harding, Page, Falconer, & Cooper, 2015; Mitchell, Pate, Dowda, et al., 2012) or decrease (Olds et al., 2009) during adolescence. Although findings are mixed, there appears to be more support for an increase in sedentary behavior as youth age (Pate et al., 2011). Studies also indicate that there are children who maintain high levels of sedentary behavior during adolescence (Mitchell, Pate, Beets, & Nader, 2012), and there are those who engage in low amounts of sedentary activities (< 2 hours/day of screen time; Iannotti & Wang, 2013; Liu, Kim, Colabianchi, Ortaglia, & Pate, 2010). How sedentary behavior changes from adolescence to emerging adulthood, and determinants of this change, however, have been relatively unexplored.

This study filled an important gap in the literature and extended previous findings by examining the trajectory of sedentary behavior from adolescence to emerging adulthood using a large representative sample of US adolescents from the National Longitudinal Study of Adolescent to Adult Health (Add Health). Specifically, this study used latent growth modeling (LGM) and a cohort-sequential design to model the trajectory of sedentary behavior (average total hours/week spent watching television and videos, and playing video or computer games) from adolescence to emerging adulthood (ages 13-23 years). In addition, it examined whether gender, parental education and limits on screen time, household income, perception of neighborhood safety, race/ethnicity, BMI, physical activity, and employment status were associated with aspects of this trajectory.

The following review of the literature will define sedentary behavior and how it is operationalized and measured, and discuss the amount of time adolescents and adults spend in sedentary behavior. Studies examining change in sedentary time among adolescents and emerging adults will also be addressed, as well as factors that may predict change.

Sedentary Behavior

Sedentary behavior refers to behaviors that involve excessive time sitting, low levels of energy expenditure [1.0 -1.5 metabolic equivalent units], and little movement (Marshall & Ramirez, 2011; Owen, Healy, Matthews, & Dunstan, 2010). It, however, does not refer to the absence of physical activity and is, in fact, distinct from physical activity (Marshall & Ramirez, 2011). For instance, it is possible for an individual to meet physical activity recommendations and still spend a significant amount of time in sedentary pursuits (Owen et al., 2011). Evidence also suggests that adolescents may have low levels of moderate physical activity and spend little time in screen-based sedentary behavior (Heitzler et al., 2011). The most common sedentary behaviors include using a computer, playing video or computer games, sitting while socializing, surfing the Web, and watching television, the most frequently measured behavior (Hardy et al., 2013; Marshall & Ramirez, 2011; Pate et al., 2011).

When it comes to assessing sedentary behavior, self-report questionnaires and objective measures are used. Neither method captures all the various aspects of sedentary behavior when used alone and researchers typically select one based on the aims and outcomes of their studies (Hardy et al., 2013). In general, self-report instruments are inexpensive, frequently utilized, and easy to administer in large studies (Hardy et al., 2013). In addition, they provide the added benefit of allowing researchers to obtain information about the type of sedentary activity in which an individual is engaging and the context in which it takes place (Hardy et al., 2013). This approach to capturing sedentary time often relies on the use of investigator-developed items or questionnaires, since no standardized or well-established instrument exists (Marshall & Ramirez, 2011).

A few studies have found support for the reliability and validity of self-report items or questionnaire. For instance, one found that the intra-class correlation coefficient for 7-day test-retest reliability of weekly hours viewing television was $r = 0.76$ for boys and 0.81 for girls (Vereecken, Todd, Roberts, Mulvihill, & Maes, 2006). Compared to studies examining the reliability of self-report measures of sedentary behavior, even less research has focused on assessing their validity (Lubans et al., 2011). Hardy, Bass, and Booth (2007) examined the construct validity of self-report items that inquired about girls' (ages 12-15) time spent engaging in a variety of sedentary activities, including watching television, playing video games, and traveling in a car. Construct validity was determined by comparing participants' responses to data collected from accelerometers they wore. Findings indicated that the mean difference in time spent in sedentary activities between self-report and accelerometer-based measures was 3.2 hours per week and suggested that the self-report questionnaire had adequate validity. Apart from the limited information on the reliability and validity of self-report measures, it is important to note that they are susceptible to recall bias and may be associated with socially desirable responding (Lubans et al., 2011). Despite this, the benefits associated with utilizing this method contribute to its widespread use (Lubans et al., 2011).

Another means of determining time spent in sedentary behavior is the use of objective measures (Hardy et al., 2013). This approach includes direct observation and motion devices such as inclinometers that assess whether someone is standing, sitting, or laying, and accelerometers, which measure the frequency, intensity, and duration of an activity (Hardy et al., 2013; Marshall & Ramirez, 2011). Of these approaches, accelerometers are utilized most often and provide both reliable and valid estimates of sedentary time (Lubans et al., 2011). For example, the reliability of accelerometers, determined by calculating the intraclass correlation coefficient, reportedly ranged from 0.67-0.79 for boys and 0.64-0.80 for girls (Barreira et al., 2015). Another study that assessed the criterion validity of accelerometers by comparing them to metabolic units found that accelerometers had excellent validity (area under ROC curve ≥ 0.98; Treuth et al., 2004; Wen, Van der Ploeg, Kite, Cashmore, & Rissel, 2010). Unlike self-report measures, however, they tend to be costly and fail to provide information about the kind of sedentary activity in which a participant engages (Hardy et al., 2013; Lubans et al., 2011). Other limitations of accelerometers are that they are unable to differentiate sitting from standing with minimal movement (Lubans et al., 2011) and may result in variable estimates of sedentary time depending on the cut-points used (Pate et al., 2011). In general, they are typically used in smaller studies and less frequently than self-report measures (Hardy et al., 2013; Marshall & Ramirez, 2011).

In sum, sedentary behavior is a separate construct from physical activity and consists of activities that involve sitting and low levels of energy expenditure. Self-report measures and accelerometers are often utilized to assess sedentary behavior; however, neither approach when used alone captures all the various aspects of sedentary behavior (Hardy et al., 2013). While there are limitations to both of these approaches, self-report instruments are more commonly employed and are easier to administer, particularly in large-scale studies.

Time spent in sedentary behavior

Several studies indicate that most adolescents spend a large portion of the day in sedentary pursuits, and often exceed the recommendations for screen time (Pate et al., 2011; Salmon et al., 2011). One study found that 15 to 17 year-olds in the US spent 7.6 and 8.0 hours/day in screen and non-screen based sedentary activities, respectively

(Wight, Price, Bianchi, & Hunt, 2009). In addition, data from the 2013 Youth Risk Behavior Survey (YRBS) showed that 32.5% of high school students spent more than 3 hours/day watching television (Kann et al., 2014).

Although fewer studies have focused on sedentary time in young adults, results also indicate that they spend a significant amount of time in sedentary behavior. In particular, one study reported that college students (21 years ± 4 years) spent an average of 29.72 hours/week in sedentary behavior and 10.56 and 5.96 hours/week watching television/videos and using a computer, respectively (Buckworth & Nigg, 2004). Another cross-sectional study using accelerometers found that adults aged 20-29 years engaged in 7.47 hours/day of sedentary behavior and those aged 30-39 years spent 7.25 hours/day in sedentary time (Matthews et al., 2008).

Longitudinal Change in Sedentary Behavior

Of the few studies examining the trajectory of sedentary behavior, most have assessed changes that occur during adolescence. Very few, however, have investigated sedentary behavior change among individuals between the ages of 18 to 25. The tendency to focus on adolescents is not specific to sedentary behavior studies, and has also been recognized by other researchers. For instance, Zarrett and Eccles (2006) noted that early adolescence and the various changes that occur during this period have been well studied. This is in part due to the fact that adolescence is characterized by biological, social, and psychological changes, and is a critical period for establishing lifelong health behaviors

(Holmbeck, 2002). While it is important to understand sedentary behavior and other health outcomes during adolescence, it is also necessary to evaluate change that occur during the transition to and throughout emerging adulthood.

Arnett (2000) argues that emerging adulthood, which refers to the period from around ages 18 to 25, is an important phase to examine since it is distinct from adolescence and young adulthood. This period represents the stage between adolescence and young adulthood that is accompanied by transitions such as entry into college or the workforce and leaving the home (Arnett, 2000; Zarrett & Eccles, 2006). Another defining aspect of this period is the amount of demographic variability observed among individuals, particularly with respect to marital/relationship status, living arrangement, enrollment in school, and parenthood (Arnett, 2000). Furthermore, as emerging adults become more independent, the role that family and related influences play in the lives of these individuals shift from what it was once during childhood and adolescence (Nelson, Story, Larson, Neumark-Sztainer, & Lytle, 2008).

Emerging adulthood is also often marked by feelings of not yet being an adult, semi-autonomy, and identity exploration and development in terms of work, worldview, and love (Arnett, 2000). Since identity (e.g., making a healthy lifestyle a part of one’s self-concept) is a marker of enduring health behavior change, emerging adulthood may be a critical time for developing long-term health behavior patterns (Storer, Cychosz, & Anderson, 1997). In addition, the evidence suggests that it may also be a time during which health behaviors change. For instance, one study noted that this period may be a time for increased weight gain and the development of obesity (Nelson et al., 2008). An Add Health study also reported that of those meeting physical activity recommendations and achieving favorable amounts of screen time (≤ 14 hours/week) during adolescence, only 4.4 % and 37.0% continued to maintain favorable amounts of physical activity and screen time, respectively, as adults (Gordon-Larsen, Nelson, & Popkin, 2004). These findings suggest that health behavior patterns during adolescence may differ from those during emerging adulthood.

As such, since adolescence and emerging adulthood may serve as important periods for establishing health behaviors, it is critical to understand how these behaviors, particularly sedentary activities, change and the factors that may influence them. Furthermore, given that these periods are typically characterized by different life experiences, the changes in and determinants of health behaviors during adolescence may differ from those during emerging adulthood (Williams, Holmbeck, & Greenley, 2002). Although little is known regarding sedentary behavior, it is reasonable to expect that these assertions would also hold for it.

Sedentary Behavior Change During Adolescence

In considering studies that examined sedentary behavior change, the majority of which were conducted outside of the US, findings indicate that sedentary behavior increases during adolescence. However, results pointing to a decrease during this developmental period have also been observed. One study conducted on 9-year-old European children, who were assessed at baseline and 6 to 10 years later using accelerometers, found that sedentary time increased 15 and 20 minutes per day per year for girls and boys, respectively (Ortega et al., 2013).

Other studies assessing sedentary behavior at more than two time points also report increases during adolescence. For instance, among 12-year-old boys and girls from the United Kingdom, who were assessed with accelerometers biennially until 16 years of age, sedentary behavior was shown to increase 19.5 and 22.8 minutes per day per year for boys and girls, respectively (Mitchell, Pate, Dowda, et al., 2012). Similar findings of an increase in sedentary behavior were observed in Estonian 11 to 12 year-olds who were assessed four times during a 22-month period using the 3-Day Physical Activity Recall (Raudsepp, Neissaar, & Kull, 2008). Another study that followed 11-year-old Vietnamese children annually for 5 years found that sedentary behavior, measured using a self-report questionnaire and accelerometers, increased with age (Trang et al., 2013). Specifically, self-reported screen time increased from 160 minutes/day to 215 minutes/day for boys, and increased from 144 minutes/day to 190 minutes/day for girls (Trang et al., 2013).

In contrast to studies pointing to an increase in sedentary behavior during adolescence, there is evidence that sedentary behavior may decrease. In particular, one study that used computerized activity diaries to assess sedentary behavior in children and adolescents between the ages of 10 and 18 reported that screen time peaked around ages 12 to 14 years and subsequently declined rapidly (Olds et al., 2009). Interestingly, researchers also found that while television time decreased from ages 12 to 17, time spent in non-screen sedentary behavior (e.g., talking with friends) increased from 2 to 9 hours per day during this period (Olds et al., 2009). These results suggest that the variability in findings on how sedentary behavior changes among adolescents may be due, in part, to the types of sedentary activities examined.

Sedentary Behavior Change from Adolescence to Emerging Adulthood

As most research on the trajectory of sedentary behavior has focused on adolescence, data on changes from this developmental period to emerging adulthood are lacking. Findings from one study using accelerometers pointed to no significant increase in sedentary behavior from adolescence to age 25 (Ortega et al., 2013). In contrast, a cross-sectional accelerometer study reported that sedentary time was lowest among 6-11 year-olds (6.1 hours/day), increased by ages 16-19 years (8.0 hours/day), but decreased among young adults ages 20-29 years (7.5 hours/day; Matthews et al., 2008). Although tests were not conducted to determine if these differences in sedentary time among the various age cohorts were significant, the authors noted that there was a significant linear trend by age for the entire sample (ages 6-85 years) and for youth and adults (Matthews et al., 2008).

A few limitations of prior studies need to be addressed to understand how sedentary behavior changes from adolescence to emerging adulthood, particularly among US youth. First, some studies used a cross-sectional approach (e.g., Olds et al., 2009) to examine differences in sedentary behavior, whereas others only assessed sedentary behavior at two time points (Gordon-Larsen et al., 2004; Ortega et al., 2013). Unfortunately, these approaches do not provide the ability to determine the shape of the sedentary behavior trajectory. In addition, they preclude the use of statistical methods, such as growth modeling, which require more than two assessments and are better suited for examining longitudinal change. Second, while some studies employed a prospective design and measured sedentary behavior on multiple occasions, participants resided in Europe (Mitchell, Pate, Dowda, et al., 2012; Raudsepp et al., 2008) and Vietnam (Trang et al., 2013), and assessments occurred only during their adolescence. By examining longitudinal changes in sedentary behavior in US youth using multiple time points, these limitations can be addressed and the generalizability of previous findings to US youth can be determined.

In sum, there is a dearth of studies investigating changes in sedentary behavior among adolescents and young adults. Although most research indicates that it may increase over time, findings have been mixed and most studies were conducted outside of the US. Unfortunately, these factors make it difficult to characterize the trajectory of sedentary behavior among US adolescents. In order to do so, longitudinal studies on youth living in the US are needed.

Factors Associated with Longitudinal Change in Sedentary Behavior

Apart from research on changes in adolescents' sedentary time, another important area in need of study is factors associated with longitudinal change in sedentary behavior. As very few studies have examined such factors, there is limited insight into what may impact sedentary behavior change, particularly during emerging adulthood (Tanaka, Reilly, & Huang, 2014). Evidence suggests that having a mother with a high educational level is associated with more time spent in accelerometer measured sedentary behavior from ages 12 to 16 (Mitchell, Pate, Dowda, et al., 2012). The researchers speculated that this may be due to parents emphasizing high academic achievement, which may lead to more time spent sitting and studying (Mitchell, Pate, Dowda, et al., 2012). On the contrary, another study found that parental education did not predict time spent watching television, playing video games, and using a computer among 9-12 year olds who were followed up 5 years later (Lee, Bartolic, & Vandewater, 2009). The different means of assessing sedentary behavior in these two studies, however, may explain the discrepant findings on the role of parental education in sedentary behavior change.

Gender may also determine how sedentary behavior changes (Ortega et al., 2013). In particular, Ortega et al. (2013) found that boys experienced significantly greater increases in sedentary behavior over time than girls (a yearly rate of 20 and 15 minutes/day, respectively) from age 9 to age 15 years. Lee et al. (2009) also reported that gender (being a boy) at baseline was associated with more time spent playing video games at the 5-year follow-up. No significant association between gender and television viewing or computer use was observed (Lee et al., 2009).

Correlates of sedentary behavior. Other potential factors that predict longitudinal change are suggested by studies examining the correlates of sedentary behavior. Cross-sectional findings suggest that parental education and gender, as well as parental limits on television viewing, income, feeling safe in one's neighborhood, race/ethnicity, BMI, physical activity, and participant's employment status are related to sedentary behavior. Specifically, studies have found that adolescents whose parents have high education levels spend less time in sedentary behavior (Van der Horst et al., 2007). In terms of gender differences, boys have been shown to be more sedentary than girls (Trang et al., 2013; Van der Horst et al., 2007). In addition, college men were found to spend more hours/week watching television/videos and using a computer than college women (Buckworth & Nigg, 2004).

Results indicating the opposite have also been observed, with two of the three accelerometer studies available reporting that girls may be more sedentary (Pate et al., 2011). One study that used NHANES 2003-2004 accelerometer data found that boys aged 6-11, 12-15, and 16-19 years were sedentary for 6.0, 7.4, and 7.9 hours/day, respectively (Matthews et al., 2008). In contrast, girls in these age groups spent 6.1, 7.7, and 8.1 hours/day in sedentary behavior, respectively (Matthews et al., 2008). The authors also noted that women were significantly more sedentary than men before 30 years of age (Matthews et al., 2008). Similarly, another study using accelerometers reported that on average girls spent 7 more minutes in sedentary behavior than boys and this difference was statistically significant (Belcher et al., 2010).

Parental limits on screen time may also be a correlate of screen time. Cross-sectional studies show that adolescents whose parents place limits on their screen time engage in less screen-based sedentary behavior compared to those whose parents do not (Lee et al., 2009; Pate et al., 2011). In one US study, parents' limiting of children and adolescents' time was measured using items that focused on the limits placed on television time and how late children can stay up at night, parents controlling how time after school is spent, and parents setting a time for when homework is done (Lee et al., 2009). According to the results, parental limit setting was associated with less time watching television and playing video games (Lee et al., 2009). It was also associated with less time using a computer at the 5-year follow-up (Lee et al., 2009).

Findings from several studies suggest that income may be related to time spent in sedentary behavior; however, findings have been inconsistent. For example, Sisson et al. (2009) reported that children and adolescents (ages 2-15 years) from low and middle income families were more likely to spend two or more hours per day in screen time compared to those from higher income families. Studies in children, adolescents (Pate et al., 2011) and adults (Rhodes, Mark, & Temmel, 2012) also point to a relationship between higher income or socioeconomic status and less time spent watching television. On the other hand, Kozo et al. (2012) noted that adults (ages 20-66 years) from higher income neighborhoods spent more time being sedentary, based on objectives measures, and reported spending more time using a computer/Internet compared to those from low-income neighborhoods. Studies have also found no association between income and sedentary time (Pate et al., 2011; Rhodes et al., 2012). Based on the evidence available, it appears that the relationship between income and screen-based sedentary behaviors is inconclusive.

Neighborhood safety is another potentially important, but less researched, factor that can influence children and adolescents' activity related behaviors. Studies suggests that children's neighborhoods can impact their development and use of time (Lee et al., 2009). To date, there is evidence that feeling safe in one's neighborhood is associated with higher levels of physical activity (Molnar, Gortmaker, Bull, & Buka, 2004). Fewer studies, however, have examined whether perception of safety is associated with sedentary behavior. Norman et al. (2005) assessed parents' perception of their neighborhoods, including pedestrian/traffic safety and crime safety, and found that it was unrelated to 11 to 15 year olds' time spent in sedentary behavior. Researchers have found, however, that parents' perception of neighborhood safety (e.g., road safety) may differ from that of their child/children (Timperio, Crawford, Telford, & Salmon, 2004).

Given that the Norman et al. study focused on parents' perception of neighborhood safety and not that of the child's, more research is needed to determine the impact of the child's perception on his/her sedentary time.

Although few studies have focused on racial/ethnic differences in sedentary behavior, research indicates that ethnic minority adolescents in the US are more sedentary and watch more television than non-Hispanic whites (Gordon-Larsen, McMurray, & Popkin, 1999; Kann et al., 2014; Pate et al., 2011; Van der Horst et al., 2007). Sisson et al. (2009) reported that 66.1% of African American and 46.1% of Mexican American compared to 42.5% European American adolescents spent ≥ 2 hours/day in screen time. In line with these findings, a study using NHANES 2003-2006 accelerometer data revealed that Mexican American and African American adolescents spent significantly more time (7 minutes) in sedentary behavior than non-Hispanic White youth (Belcher et al., 2010). Interestingly, other studies found that, overall, there were no significant racial/ethnic differences in accelerometer based sedentary behavior among children and adolescents ages 12-19 years (Whitt-Glover et al., 2009). Among adults, several studies indicate that African Americans spend more time watching television than other ethnic groups in the US (Rhodes et al., 2012). Other studies, however, reported no association between sedentary behavior and ethnicity (Rhodes et al., 2012).

In terms of BMI, findings have been mixed among adolescents and adults. Some studies showed a positive association with watching television and videos (Pate et al., 2011; Rhodes et al., 2012; Van der Horst et al., 2007) and others reported no relationship between BMI and screen based behaviors (watching television/videos, playing computer/video games, using a computer; Pate et al., 2011; Rhodes et al., 2012).

Similarly, evidence regarding an association between physical activity and screen based sedentary behavior among adolescents and adults has been inconsistent. Some studies indicated that there is a null association between the two (Pate et al., 2011), while others reported a negative, but small, association between sedentary behavior and physical activity for adolescents (Pearson, Braithwaite, Biddle, Sluijs, & Atkin, 2014; Robinson et al., 1993) and adults (Beunza et al., 2007; Rhodes et al., 2012).

The relationship between employment status and sedentary behavior has been examined in several studies focusing on adults. Findings indicated that unemployment was associated with more time spent watching television (Rhodes et al., 2012). With respect to computer use, the results have been more inconsistent with some studies showing a positive association between unemployment and computer use, and others reporting null findings (Rhodes et al., 2012).

Overall, there is insufficient evidence on the determinants of sedentary behavior change in adolescents and adults, and this may be due to the lack of prospective studies in this area (Uijtdewilligen et al., 2011). Findings suggest that among adolescents, high maternal education and gender are associated with change in sedentary behavior; however, results have been inconsistent and whether these factors are related to sedentary change from adolescence to emerging adulthood remains unknown. In addition, the findings regarding income, race/ethnicity, BMI and physical activity among adolescents and adults are mixed and may be due to variability in how sedentary behavior was assessed, the types of sedentary behavior examined or the statistical method used to analyze the data. On the other hand, more consistent results have been observed for parental limits on screen time during adolescence and employment status during adulthood. Since parental education, parental limits, income, race/ethnicity, BMI, physical activity, and employment status have yet to be examined as predictors of longitudinal change in sedentary behavior from adolescence to emerging adulthood, doing so may serve as a viable step in identifying characteristics to attend to when seeking candidates for sedentary behavior interventions.

Conclusion

In conclusion, adolescents and adults spend a significant amount of time in sedentary behavior. In addition, the review of studies highlights significant gaps in the literature and inconsistent findings regarding how sedentary behavior changes over time. While a few studies have examined longitudinal change in sedentary behavior, very few have focused specifically on determining how it changes from adolescence to emerging adulthood. In addition, very little research has been conducted on factors associated with longitudinal change in sedentary behavior. However, the use of the bioecological model and findings from studies on sedentary behavior correlates may provide insight into predictors of the trajectory. In light of the gaps in the literature, it is important to characterize the trajectory of sedentary behavior from adolescence to emerging adulthood among US youth and identify determinants of change.

Rationale and Hypotheses

The high level of sedentary behavior among adolescents is concerning, particularly given evidence demonstrating an association with an increased risk of obesity, diabetes and all-cause mortality in adults (Grøntved & Hu, 2011; Mitchell et al., 2013; Thorp et al., 2011). Findings indicating that there are individuals who maintain high levels of sedentary behavior during adolescence (Mitchell, Pate, Dowda, et al.,

2012) underscore the need to not only reduce sedentary time, but also understand how sedentary behavior changes during emerging adulthood. Failing to address this topic and the factors associated with the trajectory of sedentary behavior may hamper efforts to identify and prevent highly sedentary adolescents from becoming highly sedentary adults.

Previous studies have attempted to determine how sedentary behavior changes; however, findings were often limited due to the use of a cross-sectional design, the assessment of sedentary behavior at only two time points, and the focus only on change that occurred during adolescence. In addition, most studies were conducted on youth living outside of the US, reducing the ability to generalize outcomes to US adolescents. In spite of these limitations, the available evidence suggests that sedentary behavior increases during adolescence. In addition, one study observed a significant linear trend in which hours/day spent in sedentary behavior increased from childhood to adulthood (Matthews et al., 2008). Results that point to a decrease (Olds et al., 2009), however, prevent any reliable conclusions about longitudinal change in sedentary behavior from being drawn. In addition, very little is known about sedentary behavior change from adolescence to adulthood due to the lack of prospective studies examining this topic.

Research on factors associated with longitudinal change in sedentary behavior during adolescence suggests that parental education (Mitchell, Pate, Dowda, et al., 2012) and gender (Ortega et al., 2013) may be important to consider. Other possible factors may be drawn from cross-sectional studies, some of which indicate that parental limits on screen time, household income, race/ethnicity, BMI, physical activity, and employment status are associated with time spent in sedentary behavior. However, it is unclear whether these factors, along with gender and parental education, are associated with the trajectory of sedentary behavior from adolescence to emerging adulthood. Given that these developmental periods differ from each other, it is possible that the change in sedentary behavior and the determinants of change during these periods could vary.

Considering the limitations highlighted above, this study addressed a few important gaps in the literature. Specifically, this study examined the trajectory of sedentary behavior from adolescence to emerging adulthood by applying latent growth modeling (LGM) to a cohort-sequential design. In addition, piecewise LGM was used to evaluate whether gender and parental education, as well as factors not previously examined (parental limits on screen time, race/ethnicity, BMI, and physical activity), served as determinants of the sedentary behavior trajectory during adolescence (ages 13 to 18) and emerging adulthood (ages 19 to 23 years). Lastly, as most longitudinal studies were conducted outside of the US, this study focused on a nationally representative sample of US adolescents.

Based on findings suggesting that sedentary behavior may increase during adolescence and evidence supporting a linear increase from adolescence to adulthood (Matthews et al., 2008), it was hypothesized that:

Hypothesis 1. Sedentary behavior would increase linearly from adolescence to emerging adulthood (ages 13 to 23).

In addition, given previous research on the correlates of sedentary behavior among adolescents it was expected that:

Hypothesis 2. Gender, parental education, parental limits on screen time, household income, perception of neighborhood safety, race/ethnicity, BMI, and physical activity, would be associated with the trajectory of sedentary behavior. Specifically, gender (being a boy) and being an ethnic minority (African American, Hispanic, Asian, Native American) would be associated with higher levels of sedentary behavior at baseline and greater rates of increase. On the other hand, high levels of parental education, parental limits on screen time, higher household income, and feeling safe in one's neighborhood would be negatively associated with initial levels of sedentary behavior. These factors would also be associated with lower rates of increase. In addition, BMI and physical activity would only be associated with initial sedentary behavior levels and not rate of change. In particular, higher BMI would be associated with more initial time spent in sedentary behavior, whereas physical activity would be negatively related to being sedentary.

Finally, since the role that family related factors play may shift during emerging adulthood (Nelson et al., 2008), it was hypothesized that:

Hypothesis 3. Parental education, parental limits on screen time, household income, and perception of neighborhood safety would be unrelated to sedentary behavior change during emerging adulthood. Given the inconsistent findings regarding BMI and physical activity in previous studies, these variables were expected to be unrelated to sedentary behavior change. However, gender (being a boy), being an ethnic minority (African American, Hispanic, Asian, Native American), and not working would be associated with higher rates of increase in sedentary behavior.

Chapter 2 – Method

Procedure

This study used publicly available, de-identified, existing data from Add Health. The focus of Add Health was on factors that influence adolescents' health behaviors, as well as how these behaviors impact health outcomes in the transition to adulthood. Data were collected at four waves (Wave I: 1994-1995; Wave II: 1996; Wave III: 2001-2002, and Wave IV: 2007-2008) on a nationally representative sample of US adolescents in grades 7-12 using in-home interviews and in-school questionnaires (Chen & Chantala, 2014). The public-use data (N = 6,504 at Wave I; ages 11-21 years) consists of a random subsample of approximately half of the core sample (N = 12,105) and half of an oversampling of African American adolescents who had a college-educated parent (N = 1,038). The core sample was derived from over 90,000 students, who had an unequal probability of being selected and who completed the in-school questionnaire (Chen & Chantala, 2014). Students at each school were then stratified by grade and sex, and students at each stratum were randomly chosen to be a part of the core sample. In the public-use datasets, information is available for 4,834 participants at Wave II (ages 11-21 years), 4,882 at Wave III (ages18-26 years), and 5,114 at Wave IV (ages 24-32 years). Data in the public-use files are the same as those available in the restricted use-data and include sampling weights, except that the public-use data consist of a smaller sample and does not include data that could link siblings and friends. In addition, the pubic-use data set does not include other files, such as those relating to genetics and political context.

The Institutional Review Board (IRB) at the University of North Carolina, Chapel Hill, approved Add Health data collection and the IRB at the University of Miami has approved the current study and deemed it to be exempt.

Participants

Participants were 3705 adolescents (1716 boys, 1989 girls) from Add Heath's public-use data who were ages 13-19 years at Wave I (1994-1995). Participants were excluded if they were younger than 13 and older than 19 years (due to the small sample size for these ages), their birth month and year were missing, or their sampling weights were missing.

Measures

The variables of interest from Waves I-IV are specified below.

Demographics. Participants' ages were based on responses at each wave, and gender and race/ethnicity were based on their Wave I responses. Race/ethnicity were dummy coded with four vectors: African American (1, 0, 0, 0); Asian (0, 1, 0, 0); Hispanics (0, 0, 1, 0); Native American (0, 0, 0, 1); and non-Hispanic whites (0, 0, 0, 0).

Sedentary behavior. Sedentary behavior at Waves I-IV was assessed using 7-day recall items, which are appropriate for epidemiologic studies (Gordon-Larsen, McMurray, & Popkin, 2000; Nelson, Gordon-Larsen, Adair, & Popkin, 2005). At Waves I-III, sedentary behavior was examined using three questions: 1) *How many hours a week do you watch television*; 2) *How many hours a week do you watch videos*; and 3) *How many hours a week do you play video or computer games?* The two available questions at Wave IV used to assess sedentary time were: 1) *In the past seven days, how many hours did you watch television or videos, including VHS, DVDs or music videos? and* 2) *In the* *past seven days, how many hours did you spend playing video or computer games, or using a computer? Do not count Internet use for work or school.* Participants' total sedentary time (hours/week) at each wave was calculated and these values were then used to determine sedentary behavior for each age (13-32 years). The Cronbach's alpha for the items used to calculate total sedentary time was .50 at Wave 1, .46 at Wave 2 and .51 at Wave 3.

Parental education. Parental level of education was obtained using the Wave 1 question, *How far in school did you go?* There were 9 response options that ranged from "8th grade or less" to "professional training beyond 4-year college/university." These responses were dummy coded with three vectors: less than high school (1, 0, 0, 0); high school graduate or completed General Education Development test (0, 1, 0, 0); did not graduate from college (0, 0, 1, 0); college graduate professional training beyond 4-year college/university (0, 0, 0, 0).

Parental limits on television viewing. Two items from Wave I examined parental limits on screen time: *Do your parents let you make your own decisions about how much television you watch?* and *Do your parents let you make your own decisions about which television programs your watch?* Questions similar to these have been previously used to assess parental limits on screen time (Lee et al., 2009). Response options for the items (yes or no) were collapsed across the two question and dichotomized to reflect whether any limits were set (1) and whether no limits were set (0).

Household income. Household income was obtained from participants' parent/guardian response to the Wave I question *About how much total income, before taxes, did your family receive in 1994?*

Neighborhood safety. Participants' perception of the safety of their neighborhood was determined using the Wave I question *Do you usually feel safe in your neighborhood?* Response options included "yes" (1) or "no" (0).

Body mass index. Body mass index (kg/m^2) was calculated using self-reported height (feet) and weight (inches) at Wave I. Measured height and weight, available only at Waves II-IV, were used to assess the correspondence between participants' self-reported height and weight collected during these waves. At Waves II, III and IV, the Pearson correlations between measured and self-reported height were .94, .96, and .94, respectively. In addition, the correlation between measured and self-reported weight across Waves II to IV were .95, .98, and .98. Of note, participants did not systematically over report their height and underreport their weight. Approximately one-third of the sample accurately self-reported these measures, a third over reported, and a third underreported. The high concordance between participants' actual and reported height and weight suggests that they were accurate at reporting this information.

Physical activity. Physical activity was examined with three Wave I questions that used a 7-day recall method similar to those utilized for epidemiologic studies (Gordon-Larsen et al., 2000; Kann et al., 2014). These questions were: *During the past* *week, how many times did you:* 1) *go roller-blading, roller-skating, skateboarding, or bicycling;* 2) *play an active sport, such as baseball, softball, basketball, soccer, swimming, or football*; and 3) *do exercise, such as jogging, walking, karate, jumping rope, gymnastics or dancing?* Response options were "not at all," "1 or 2 times," "3 or 4 times," and "5 or more times." Items were combined to determine the total bouts of physical activity during the week.

Employment status. At Wave III, participants' employment status was assessed using the questions: *Do you currently have a job* and *Are you currently enrolled in school or in a job training or vocational education program?* These two questions were combined to create a variable that was dummy coded into three vectors: in school only (1, 0, 0, 0); in school and working (0, 1, 0, 0); not in school and not working (0, 0, 1, 0); and working only (0, 0, 0, 0).

Chapter 3 – Data Analysis

SAS (version 9.3) was used to identify outliers and patterns of missingness, assess for distributional assumptions, and conduct descriptive analyses. Post-stratification sampling weights and cluster units were used to reflect population estimates and account for the complex sampling design.

Latent growth curve modeling, which serves as a flexible and powerful means of examining longitudinal data was used to determine how sedentary behavior changed from adolescence to adulthood. One notable aspect of LGM is that it allows for the specification of a variety of functional forms (Duncan & Duncan, 2009). For instance, it can provide information on the intercept factor, which represents the initial levels of an outcome, and the slope factor, or the average rate of change, in a linear model (Duncan, Duncan, Strycker, & Chaumeton, 2007). In a quadratic model, another factor can be added to represent the degree and direction of the curvature of the quadratic function. All factors specified in a model have a mean and a variance. Latent growth modeling also estimates the correlation among the growth factors and allows covariates to be entered into the model to determine their impact on the parameters of the function.

Latent growth modeling was performed with *Mplus* 7.4 (Muthén & Muthén,1998–2012) to determine the trajectory of sedentary behavior across ages 13-23 years. The full information maximum likelihood with robust estimators option was specified to account for missing data (21% for household income, and up to 13% for other variables) and the complex sampling design. A cohort-sequential approach was employed that uses a limited number of repeated measurements of different age cohorts to produce temporally overlapping measurements of the various age groups (Nesselroade & Baltes, 1979). This technique allows adjacent segments of limited longitudinal data from one age cohort to be linked together with similar segments from other related age cohorts to form a common growth curve (Duncan, Duncan, & Hops, 1994). In other words, each age cohort contributes to different sections of the overall curve (Duncan, Duncan, & Strycker, 2006). For example, if data were initially collected from participants, who were ages 11-13 years at baseline, and follow-up measurements were then taken a year apart for 3 years, one could look at the trajectory for the data from ages 11-16 years using a cohort-sequential approach. Participants who were 11 years old at baseline would provide information for ages 11, 12, 13 and 14; those ages 12 would contribute data for ages 12, 13, 14, 15, and so on. As such, a cohort-sequential approach allows for the examination of an outcome over age instead of measurement occasion.

Prior to running the LGM, sedentary behavior variables for each age (13-32 years) were created using data from the four waves. For example, participants who were 15 years old at Waves I and II provided data for the sedentary behavior variable for age 15. Rearranging the data in this manner allowed each time point to represent age and not the measurement occasion. Descriptive data are provided for ages 13 to 32 years, however, the growth models only examined sedentary behavior change from ages 13 to 23 years. This was due to the lack of overlap between data collected at Wave IV, when participants were 24 to 32 years old, and data collected at the other waves. Since the use of a cohort-sequential approach relies on data overlapping to form a common growth curve, the design of Add Health prevented data from Wave IV from being linked with data from the previous waves. This lack of overlap among the data was evident when attempting to run growth models that included sedentary behavior from ages 24 to 32 years. These models were unable to produce parameter estimates and standard errors due to low covariance coverage and the models not converging. Given this limitation, growth model results of sedentary behavior change are only presented for ages 13 to 23.

Latent growth modeling analyses were carried out in two steps to determine the trajectory of sedentary behavior (total hours per week spent watching television and videos, and playing video or computer games) from adolescence to emerging adulthood (ages 13-23 years) and predictors of the trajectory. For the first step, a linear unconditional growth model, in which no predictors were included, was initially specified for sedentary behavior from ages 13-23 years (Aim 1). Quadratic models were also analyzed to assess for a possible curvilinear trajectory and provided a better fit to the data, as will be discussed in the next section. Instead of using a single function to model change in sedentary behavior from ages 13 to 23, a piecewise approach was employed to model the different parts of the quadratic curve simultaneously. Using a piecewise approach allowed the slope for each period to be identified and predictors of the slopes to be examined.

Before specifying the piecewise model, the cut point in the quadratic model, or where the slope of the growth curve equaled zero, was identified. As such, the cut point represented where the trajectory changed direction and was found to be at age 18. This was consistent with the literature suggesting that youth move into emerging adulthood at this age (Arnett, 2000). A piecewise growth model was specified next to break the quadratic growth curve into two linear pieces to represent the changes in sedentary behavior from ages 13 to 18 (first slope) and from ages 19 to 23 (second slope). Using a piecewise model also allowed predictors of the intercept and the slopes to be examined.

For the second step, a conditional growth model with the following predictors was analyzed to determine whether they were associated with sedentary behavior change (Aim 2): gender, parental education and limits on screen time, household income, perception of neighborhood safety, race/ethnicity, BMI, physical activity, and employment status. All of these variables served as predictors of the intercept and the two slopes of the piecewise model, except for employment status, which was only a predictor of change from ages 19 to 23. The results below will highlight findings from the linear, quadratic, and piecewise unconditional models, and the piecewise conditional model.

For all growth models, the intercept estimates were fixed to 0 and residual variances were constrained equal, unless otherwise specified. The full information maximum likelihood estimation method was used to account for missing data, assuming that the data were missing at random (missing by design). To assess for model fit, the chi-square goodness of fit test, the comparative fit index (CFI; >.95), the root mean square error of approximation (RMSEA; ≤ .06), and the standardized root mean square residual (SRMR; ≤ .08) were used (Hu & Bentler, 1998). Confidence intervals were provided and parameter estimates were viewed as significant if p < 05.

Chapter 4 – Results

Descriptive Statistics

Participants were predominantly non-Hispanic white and more than half were girls (see Table 1 for sample characteristics). The majority of the sample reported feeling safe in their neighborhood and indicated that their parents let them make their own decisions about how much and which television programs they watched. In addition, 72.1% of participants' parents had less than a college degree. Table 2 shows the mean and standard error for total time spent in sedentary behavior from ages 13 to 32. These results indicate that sedentary behavior decreased during adolescence and increased from ages 18 until age 25, when it decreased and remained relatively stable. Findings also suggest that participants were often spending more than the recommended 2 hours per day in screen time.

Figure 1 presents data on total sedentary time per week and hours spent watching television, watching videos, and playing video/computer games from ages 13 to 23, the period examined using LGM. It appeared that the decrease in television viewing from ages 13 to 17 contributed to the decrease in total sedentary behavior during these ages. Although television viewing appeared to decrease until age 23, time spent playing video/computer games increased after age 18, and led to the increase observed in total sedentary time during emerging adulthood.

Change in Sedentary Behavior from Age 13-23 years

It was hypothesized that sedentary behavior would increase linearly from adolescence to emerging adulthood. To examine whether this occurred, a linear growth model with no predictors was specified. Results indicated that the model did not fit the data [(χ^2 (33) = 74.53, $p < .001$); RMSEA = .018 (90% CI = [.013, .024]); CFI = .91; SRMR = .18]. This suggested that a linear trajectory may not be representative of sedentary behavior change from age 13 to 23. The mean of the slope factor was not significant (b = -.005, $p = .96$); however, the mean of the intercept factor was (b = 21.35, $p < .001$). In addition, there was significant variability in adolescents' initial levels of sedentary behavior at age 13 (217.64, $p < .001$) and their linear slope, or rate of change, from ages 13 to 23 (2.86, p = < .001).

A quadratic model was examined next to determine whether it would provide a better fit to the data. The variance for the quadratic factor was fixed to 0 and the residual variances were constrained equal for ages 13 to 18 and for ages 19 to 23 years. This model fit the data [(χ^2 (31) = 38.75, $p = .16$); RMSEA = .008 (90% CI = [.000, .016]); CFI = .983; SRMR = .157] and suggested that a quadratic function was an appropriate means of representing sedentary behavior change. The negative linear slope (b = -1.95, $p < .001$) indicated that initially sedentary behavior decreased on average by 1.95 hours per week per year, and the positive quadratic term (b = .18, $p < .001$) indicated that the decline was reduced by .36 hours per week (2 x .18). In addition, the intercept was significant (b = 25.18 $p < .001$), and there was significant variability in adolescents' initial levels of sedentary behavior at age 13 (210.51, $p < .001$) and the rate of change in sedentary behavior from ages 13 to 23 (1.80, $p = .02$). The covariation between the intercept and slope (-15.42, $p < .001$) suggested that those with higher initial levels of sedentary behavior experienced greater linear decreases over time. While these findings did not support the hypothesis of a linear increase in sedentary behavior, they were consistent with the descriptive data presented in Table 2 and Figure 1.

For the next step in the analyses, the age at which the slope was equal to 0 in the quadratic growth curve was determined. As previously noted, this was done to identify the point before the curve changed direction. Determining this cut point thus allowed for the quadratic growth curve to be segmented into two linear pieces to examine change before and after the cut point. In addition, this step allowed for the differential effects of the predictors on each part of the piecewise model to be examined. To find the cut point where the slope equaled 0, the derivative of the equation derived from the parameter estimates in the quadratic model ($.18t^2 - 1.95t + 25.18$) was taken. It was found that this point was at age 18. This empirically derived cut point was consistent with research indicating that this age is an important time for adolescents since they are typically transitioning into emerging adulthood (Zarrett & Eccles, 2006).

Analyses proceeded using a piecewise model with no predictors, one intercept factor, and two slope factors. The first slope factor examined sedentary behavior change from ages 13 to 18 years and the second looked at change from ages 19 to 23 years. Results indicated that this model fit the data [(χ^2 (26) = 33.04, $p = .16$); RMSEA = .009 (90% CI = [.000, .016]); CFI = .985; SRMR = .145]. Consistent with findings from the quadratic model, sedentary behavior decreased from ages 13 to 18 years (b = -1.27, $p < .001$), but increased from ages 19 to 23 years (b = .39, $p < .001$). In particular, sedentary time decreased at a rate of approximately 1.3 hours per week per year from ages 13 to 18 and increased .39 hours per week per year from ages 19 to 23. The mean of the intercept (b = 24.99, p <.001) suggested that on average, participants spent about 25 hours per week in sedentary behavior at age 13. There was significant variability in participants' initial time spent in sedentary behavior at age 13 (b = 182.67, $p < .001$); however, there was no significant variability in the rate of sedentary behavior change from ages 13 to 18 (b = 4.09, $p = .37$) and 19 to 23 years (b = .51, $p = .37$). In addition, the covariance among the intercept and slope factors were not significant (all ps > .05).

Predictors of Change in Sedentary Behavior from Age 13-18 years

A conditional piecewise growth model was specified next to identify predictors of participants' initial levels of sedentary behavior (intercept; age 13 years) and change in sedentary behavior from ages 13 to 18 (first slope factor) and 19 to 23 years (second slope factor). The predictors included gender, parental education and limits on screen time, household income, perception of neighborhood safety, race/ethnicity, BMI, physical activity, and employment status (for the second slope only). Although the variances of the slope factors were not significant in the piecewise unconditional model, covariates were examined since the slope variance was significant in the quadratic model.

Fit indices indicated that the piecewise model with an intercept and two slope factors fit to the data [(χ^2 (159) = 197.84, $p = .02$); RMSEA = .009 (90% CI = [.004, .013); CFI = .965; SRMR = .062]. In terms of predictors of the intercept, it was hypothesized that gender (boys), ethnicity (ethnic minority), and higher BMI would be associated with greater initial levels of sedentary behavior. On the other hand, high levels of parental education and household income, parental limits on screen time, feeling safe in one's neighborhood, and physical activity would be related to less sedentary time at age 13. Findings revealed that boys spent approximately 6 more hours per week in sedentary behavior compared to girls (p < .001; see Table 3 for estimates of predictors of sedentary behavior at age 13). Higher BMI was also associated with higher initial levels of sedentary behavior (*p* = .001). Adolescents whose parents set limits on their television viewing spent approximately 12 hours less in sedentary time at age 13 (*p* = .001) compared to those whose parents did not. Higher household income levels were also associated with lower initial levels of sedentary behavior (*p* = .045). In addition, those who reported feeling safe in their neighborhood spent less time (5 hours) engaging in sedentary behavior than those who felt unsafe (*p* = .001). No significant difference in initial sedentary behavior levels were observed when comparing Hispanic, African American, Native American, and Asian adolescents to non-Hispanic whites (all *p*s > .05). In addition, parental level of education, and physical activity were not associated with initial levels of sedentary behavior (all *p*s > .05).

It was expected that gender (boys) and ethnicity (ethnic minority) would be associated with greater rates of increase in sedentary behavior. However, high levels of parental education, parental limits on screen time, higher household income, and feeling safe in one's neighborhood would be associated with lower rates of increase in sedentary time. Body mass index and physical activity were not expected to be associated with sedentary behavior change. In examining predictors of change from ages 13 to 18 years (first slope), it was found that sedentary behavior decreased at a lower rate in Asian Americans than in non-Hispanic whites (*p* = .02; see Table 4 for estimates). No significant difference in the rate of decrease was observed when comparing other ethnic groups to non-Hispanic whites. Parental limits on screen time and feeling safe in the one's neighborhood were associated with lower rates of decrease in sedentary behavior (*p*

= .02 and $p = .01$, respectively). However, gender, parental education, household income, BMI, and physical activity had no effect on the rate of change in sedentary behavior from ages 13 to 18 (all *p*s > .05).

Predictors of Change in Sedentary Behavior from Age 19-23 years

With respect to 19 to 23-year-olds (second slope), only gender, race/ethnicity and employment status were expected to be associated with sedentary behavior change. Findings revealed that African Americans and Asian Americans had a lower rate of increase compared to non-Hispanic whites ($p < .001$ and $p = .049$, respectively; see Table 5 for estimates). In addition, more bouts of physical activity were also associated with lower rates of increase in sedentary time ($p = .03$). Participants' employment status at Wave III was examined and results indicated that participants who were only in school ($p = .01$) and neither in school nor working ($p < .001$) had greater rates of increase in sedentary behavior than those who were only working. None of the other predictors was associated with change in sedentary behavior (all *p*s > .05). Overall, the predictors accounted for 30.3% of the variance in the intercept, 36.6% of the variance in the slope for ages 13 to 18 and 42.7% of the variance in the slope for ages 19 to 23.

Chapter 5 – Discussion

This was the first study to examine the trajectory of sedentary behavior from adolescence to emerging adulthood in a nationally representative sample using latent growth modeling applied to a cohort sequential design. The results obtained add to the small body of research on sedentary behavior change and showed that participants' screen time from ages 13 to 23 was best modeled with a quadratic function. In particular, sedentary behavior decreased from ages 13 to 18 but then increased from ages 19 to 23. A piecewise model allowed predictors of the slopes, representing change from ages 13 to 18 and 19 to 23, to be assessed to determine their impact on sedentary behavior change. The predictors included gender, parental education and limits on screen time, household income, perception of neighborhood safety, race/ethnicity, BMI, physical activity, and employment status. Since many of these factors were previously identified as correlates of sedentary behavior, this study extended prior findings by determining whether they were also associated with change in sedentary time.

Sedentary Behavior Change

The hypothesis that sedentary behavior would increase linearly from adolescence to emerging adulthood was not fully supported. A quadratic growth model provided a better fit to the data and, along with descriptive statistics, suggested that there was a period when sedentary behavior was decreasing but that trajectory then changed around age 18. In particular, sedentary time decreased from ages 13 to 18, but increased from ages 19 to 23. Despite the decrease in sedentary behavior, however, adolescents continued to spend more than 14 hours per week on average in screen time during adolescence and emerging adulthood. The high levels of sedentary time could be in part due to the steady increase in access to a computer and the internet in the US during the study period. Census data indicate that in 1993, 22.9% of households had a computer and in 2001 this increased to 56.3% (File, 2013). By 2007, 69.7% of homes had a computer. Census data for internet use at home were first collected in 1997 and showed that the rise in internet use at home paralleled that of computer ownership. In 1997, 2001, and 2007, the percentages of home with internet were 18%, 50.4%, and 61.7%, respectively.

Olds et al. (2009) reported similar findings regarding overall screen time (television, computer, and video games) in a sample of 10-18-year-old Australian children and adolescents. They found that self-reported screen time peaked at age 12, but declined thereafter (Olds et al., 2009). When examining the different screen-related behaviors separately, they noted that television time decreased from ages 12 to 17 and video game time decreased for boys only from ages 10 to 18 (Olds et al., 2009). A recent study examining trends in sedentary behavior also reported that hours per week of television viewing decreased from 2001-2009 (Iannotti & Wang, 2013b).

The findings observed by Olds et al. (2009), Iannotti and Wang (2013b), and the current study were in contrast, however, to reports of an increase in sedentary behavior during adolescence (Mitchell, Pate, Dowda, et al., 2012; Ortega et al., 2013). One important factor that may explain the discrepant outcomes is the manner in which sedentary behavior was assessed. The studies reporting an increase in sedentary behavior used accelerometers, which provide an account of overall sedentary time, but are unable to distinguish among the various types of behavior. Thus, the increase in sedentary time during adolescence observed in the accelerometer studies may have been driven by increases in non-screen related sedentary behaviors not captured in the current study. In fact, Olds et al. (2009) found that while screen time decreased during adolescence, time spent in other types of sedentary behaviors, such as doing homework and talking while sitting, increased (Olds et al., 2009). In addition, another study of adolescent 12 to 15 year-old girls reported that 45% of their sedentary time was spent doing homework, reading and studying, hanging out, and sitting talking to friends (Hardy et al., 2007). Thirty-three percent of their sedentary time, however, was spent in screen-related behaviors (watching television and videos, and playing computer games). As such, it is possible that adolescents in the current study were spending an increasing proportion of their day in non-screen related sedentary activities and this may have contributed to the decrease in their screen time.

In terms of the increase in sedentary time from ages 19 to 23, this finding was different from those reported in another study (Ortega et al., 2013). Using accelerometers, researchers found that there was no significant change in sedentary behavior from ages 15 to 25 (Ortega et al., 2013). The contradictory findings could be due to Ortega et al. (2013) using accelerometers and assessing total sedentary time per day, or to their study participants being from Sweden and Estonia (Ortega et al., 2013). Given the lack of studies examining the trajectory of sedentary behavior, particularly through emerging adulthood, more work is needed to better understand changes during this period.

If the finding of a decrease in screen time from the current study is replicated, this could have important clinical implications as interventions aimed at reducing sedentary behavior among adolescents tend to focus on screen-related activities, most commonly, watching television (Biddle, O'Connell, & Braithwaite, 2011). A recent review of these interventions noted that they had a small, significant effect on reducing sedentary time

(Biddle et al., 2011). As there is evidence that screen time may decrease during adolescence, studies that include long follow-up periods may need to determine the impact of their intervention over and above age-related changes in screen behaviors (Olds et al., 2009). In addition, the discovery of an increase in screen-related sedentary time during emerging adulthood in the current study and the high levels observed at each age in the current study suggest that continued efforts are needed to reduce screen time, particularly during adulthood.

One interesting finding was that the trajectory of sedentary behavior changed at age 18 and started to increase. This was consistent with the notion that around this age, adolescents are typically experiencing major developmental changes, one of which being the transition from high school to either college or the work force (Zarrett & Eccles, 2006). As such, their concerns typically shift to include decisions about educational training, the labor force, whether to move out or remain at home, or even parenthood (Zarrett & Eccles, 2006). These experiences and other decisions made during emerging adulthood have the potential to impact functioning and well-being in adulthood (Jekielek & Brown, 2005; Zarrett & Eccles, 2006). With this in mind, the finding of an increase in sedentary behavior from ages 19 to 23 raises concerns about the impact of such changes on participants' health outcomes as they get older, particularly since high levels of sedentary behavior in adults may elevate one's risk of developing type 2 diabetes and all-cause and cardiovascular disease related mortality (Thorp et al., 2011).

Overall, it appeared that screen-related sedentary behavior decreased from ages 13 to 18, but increased during emerging adulthood. From ages 13 to 23, however, participants spent more than 14 hours on average in screen-related activities per week, highlighting the need for continued research on ways to reduce sedentary time. Although other studies reported an increase in sedentary behavior during adolescence, this may reflect a change in non-screen related sedentary activities that were not assessed in the current study. Furthermore, while sedentary behavior increased during emerging adulthood, another study indicated that there was no significant change during this period. The limited research in this area, however, precludes any definitive conclusions about sedentary behavior change in emerging adulthood from being drawn and underscores the need for more work.

Factors Associated with Initial Levels and Change in Sedentary Behavior

Gender. Of the factors that were tested, only gender and parental education have been previously found to be associated with sedentary behavior change. With respect to gender differences in sedentary time, the finding that boys in this study had higher initial levels of sedentary behavior at age 13 than girls was in line with what was hypothesized and lends support to previous studies reporting similar results (Van der Horst et al., 2007). However, there was no support for boys experiencing greater increase in sedentary behavior during adolescence and emerging adulthood. This was inconsistent with findings from a European (Estonia and Sweden) study that used accelerometers and reported that boys had significantly greater increase in sedentary time from childhood to adolescence and from adolescence to age 25 (Ortega et al., 2013). Another accelerometer study in the United Kingdom, however, found that girls experienced greater increases in sedentary behavior from age 12 to16 compared to boys (Mitchell, Pate, Dowda, et al., 2012). The inconsistencies in the findings from these longitudinal studies and the current one may reflect region-specific differences in sedentary behavior (Ortega et al., 2013). These results may also suggest that more research is needed to further examine the role of gender in sedentary behavior changes.

Parental education. It was found that parental education was neither associated with initial levels of sedentary behavior nor change during adolescence and emerging adulthood. Although the findings for adolescents were contrary to what was hypothesized, they lend support to another longitudinal study that reported no significant relationship between parental education and screen time at baseline (ages 9 to 12) and 5-year follow-up (Lee et al., 2009). Another study, however, noted that higher levels of maternal education were associated with increases in accelerometer measured sedentary behavior from ages 12 to 16 (Mitchell, Pate, Dowda, et al., 2012). One possible explanation for the different findings across studies could be the covariates that were selected. In addition to parental education, Lee et al. (2009) used variables that assessed sociodemographic factors such as income, gender, age, and ethnicity, as well as neighborhood quality, parental limit setting on television time, family conflict, adults in the household, and time spent with parents. Mitchell et al., (2012), on the other hand, focused primarily on covariates pertaining to maternal factors such as maternal age, education, obesity, and smoking during pregnancy. As such, the inclusion of covariates other than those relating to one parent in the Lee et al. (2009) and current studies may suggest that the effect of parental education diminishes after accounting for other demographic and environmental factors. In light of this, parental education may not be as important as other covariates when considering sedentary behavior change. However, the limited research available on the relationship between education and change in sedentary time highlights the need for more work in this area.

Parental limits on television viewing. Unlike parental education, parental limits on screen time was associated with initial levels and change in sedentary behavior, but from ages 13 to 18 only. In particular, parental limits were associated with being less sedentary at age 13 and experiencing a smaller decrease in sedentary behavior from ages 13 to18. This was unexpected as it was posited that having parental limits would be related to lower rates of increase. Other cross-sectional studies have also demonstrated the effectiveness of parental limit setting on television viewing and overall screen time (Lee et al., 2009; Norman et al., 2005; Wiecha, Sobol, Peterson, & Gortmaker, 2001). These studies indicate that adolescents spent less time in screen related activities when their parents set limits. No prior research, however, had examined the impact of setting limits on sedentary behavior change.

It is possible that the lower rate of decrease for participants whose parents set limits could have been a result of their sedentary behavior remaining more stable over time compared to those whose parents did not place any limits. This notion is supported by descriptive data indicating that total sedentary behavior for those whose parents set limits was approximately 22 hours per week at age 13, went down 3 to 5 hours between ages 15 and 17, then returned to 22 hours at age 18. On the other hand, those whose parents did not place limits went from as high as 27 hours at age 13 to as low as 19 hours per week at age 18. In terms of the non-significant effect of parental limits on change in sedentary time from ages 19 to 23, it could be that the impact of parental limits is more evident during adolescence and diminishes as participants move into emerging adulthood. This may be due to reduced parental influence on adolescents' behaviors and increased levels of autonomy as they get older (Zarrett & Eccles, 2006). Since no prior study has examined the effect of parental limits on sedentary behavior change, these findings are important and suggest that it may play a role in reducing sedentary time during adolescence.

Household income. The results from the current study indicated that household income was associated with initial levels, but not change in sedentary behavior from ages 13 to 18 and 19 to 23. These results were partly in line with what was hypothesized. However, the finding of a relationship between income and initial sedentary time (at age 13) was in contrast to those reported by a cross-sectional study. Anderson, Economos, and Must (2008) found no association between participants' poverty to income ratio (family income to poverty threshold) and the likelihood of high levels of screen time. Lee et al. (2009) also observed no relationship between family income to needs ratio (family income to family poverty threshold) and television, computer, and video game time at baseline and at five-year follow-up.

Other cross-sectional studies, however, have reported a negative association between income and sedentary time. For instance, Sisson et al. (2009) found that children and adolescents from high income families were less likely to spend more than 2 hours daily in screen time compared to those from low and middle income families. In addition, an Add Health study reported that adolescents from high income families were less likely to fall into the highest inactivity category (≥ 25 hours/week) compared to participants from low income families (Gordon-Larsen et al., 2000). The inconsistent findings observed across studies could be attributed, in part, to the way in which income was assessed. The studies that did not find a cross-sectional relationship used some form of a ratio that included a measure of poverty. As such, it is uncertain whether using income alone in these studies would have resulted in similar results to those found in the current study.

In terms of the effect of income on sedentary behavior change during adolescence and emerging adulthood, findings from this study suggest that it may not play a role in adolescents' sedentary time as they get older. Given that there is no other study that has explored the impact of income, or related measures, on sedentary behavior change, it is unclear whether the lack of an association observed is specific to this study. Further examining the relationship may provide insight into whether income is a factor to consider when determining which individuals experience increases or decreases in their sedentary time.

Perception of neighborhood safety. As hypothesized, adolescents who felt safe in their neighborhood had lower initial levels of sedentary behavior compared to those who felt unsafe. However, it was unexpected that they would experience lower rates of decrease from ages 13 to18. Although sedentary behavior was decreasing at a slower rate for those who felt safe, they often spent significantly less time in sedentary behavior than those who felt unsafe (data not shown). From age 19 to 23, perception of neighborhood safety no longer had an effect on sedentary behavior change, suggesting that participants' perceptions during their adolescence may only have an impact on sedentary behavior during this period. If participants moved out of their neighborhood in which they lived during their middle and high school years, this could also contribute to their perceptions during adolescence no longer affecting their sedentary time in emerging adulthood.

These findings add to the small body of research on neighborhood safety and sedentary behavior. Previous studies that focused on either the parent's or the child's perception of safety yielded different results. Of the two studies that examined parents' perception of neighborhood safety, only one found that it was associated with time spent in sedentary behavior. Datar, Nicosia, and Shier (2013) assessed parents' perception of safety and their child's sedentary behavior in 1^{st}, 3^{rd}, 5^{th}, and 8^{th} grade and discovered that living in neighborhoods perceived as unsafe was associated with more sedentary time cross-sectionally and longitudinally. In contrast, Norman et al. (2005) observed no relationship between parents' assessment of neighborhood safety and sedentary behavior. This finding was consistent with those from another study that examined 6^{th} grade girls' views on the safety of their neighborhood (Evenson, Scott, Cohen, & Voorhees, 2007).

The inability to detect a consistent relationship between perception of neighborhood safety and sedentary behavior could be due to the measures employed. Norman et al., (2005) used a measure that was initially intended to assess the relationship between neighborhood characteristics and physical activity (Saelens, Sallis, Black, & Chen, 2003). Given that sedentary behavior and physical activity should be considered discrete constructs, tools created to assess one factor may not be an appropriate means of assessing the other (Pearson et al., 2014). Both Norman et al. (2005) and Evenson et al. (2007) also included more objective items to assess participants' perceptions. For instance, questions asked about how easy it is to see bikers and walkers in the neighborhood (Evenson et al., 2007) and whether neighborhood streets were well lit

(Norman et al., 2005). These factors, however, may not be taken into account when individuals are determining whether their neighborhoods are safe. Furthermore, it is possible for a place to not be walkable but still safe, as walkability could be affected factors unrelated to safety, such as the presence of hills. As such, while these studies focused on neighborhood safety, they were less direct at assessing individuals' perceptions. Datar et al (2013) argues that perceptions are more relevant when considering behaviors such as children's sedentary time. In addition, directly inquiring about feeling safe allows the respondent to determine which characteristics of their neighborhood are relevant to them (Datar et al., 2013). Given that a relationship was found in the current study and in Datar et al.'s (2013) when participants were explicitly asked if they felt safe, this approach may be more relevant when assessing time spent in sedentary behavior.

Race/Ethnicity. Several cross-sectional studies suggest that ethnic minorities spend more time in sedentary behavior compared to non-Hispanic whites (Pate et al., 2011; Rhodes et al., 2012). In this study, however, there was no significant difference in initial levels of sedentary time when comparing ethnic minorities to non-Hispanic whites. From ages 13 to 18, Asian Americans experienced lower rates of decrease in sedentary behavior, and, along with African Americans, had lower rates of increase than non-Hispanic whites from ages 19-23. One study found that 9-12 year-old African American and Hispanic children spent less time using a computer than whites at baseline and at the 5-year follow-up (Lee et al., 2009). In addition, Asian American adolescents spent less time playing video games than non-Hispanic whites at follow-up (Lee et al., 2009). Interestingly, ethnicity was unrelated to time spent watching a television and playing video games (Lee et al., 2009). The findings from Lee et al. (2009) and the current one suggest that the ethnic differences in sedentary time found in cross-sectional studies may not be similar to those found when examining changes in sedentary behavior. Since total sedentary time per week was assessed in this study, this may have made it difficult to identify ethnic differences that may be more evident when looking at sedentary behaviors separately. More studies examining different sedentary behaviors separately, as well as overall sedentary time, may lead to a better characterization of how these outcomes relate to race/ethnicity.

Body mass index and physical activity. Both BMI and physical activity were expected to be associated with initial levels of sedentary behavior and not rate of change. Only the findings for BMI were consistent with what was hypothesized in that higher BMI was associated with higher initial levels of sedentary behavior. While physical activity was unrelated to initial sedentary time, more bouts of activity per week were associated with lower rates of increase from ages 19 to 23. Previous cross-sectional research in adolescents and adults examining the relationship of BMI and physical activity with sedentary behavior has been mixed. Several studies and review articles indicate that there is no relationship, while others suggest that higher BMI is associated with more sedentary behavior (Pate et al., 2011; Rhodes et al., 2012). Similarly, null findings have been observed for physical activity; however, some studies note a small negative association with sedentary behavior (Beunza et al., 2007; Pate et al., 2011; Pearson et al., 2014). These inconsistent findings could be due to variability in measures used to capture sedentary behavior and physical activity (self-report vs. accelerometers), whether weight status or BMI was used. The contradictory results could also be due to differences in sample characteristics, covariates included, and data analytic strategies used (assessing sedentary behavior and physical activity as dichotomous vs continuous outcomes; logistic regression vs. multiple regression) (Bryant, Lucove, Evenson, & Marshall, 2007; Sallis, Prochaska, & Taylor, 2000).

Prospective studies examining the relationship between sedentary behavior and BMI have focused primarily on BMI as the outcome. Such studies found that an increase in sedentary behavior predicted an increase in BMI for children ages 9 to15 and 14 to 18 (Mitchell, Pate, Beets, et al., 2012; Mitchell et al., 2013). Similar findings were reported in another study that examined television watching at age 14 and 21 and its relation to BMI at age 21 (Mamun et al., 2012). Researchers found that at age 21, 50% of participants watched more than 3 hours of television per day, whereas only 35.7% did at age 14. In addition, they reported that those who watched more than 3 hours at age 14 and 21 had a higher BMI at 21 (Mamun et al., 2012). Since these studies focused on BMI as the outcome, it is unclear whether it would be linked to change in sedentary behavior. Based on findings from the current study, it appears that there is only a cross-sectional relationship between BMI and sedentary behavior and that BMI is not associated with change in sedentary behavior.

In terms of the null finding for physical activity and initial levels of sedentary behavior, this supports the notion that the two are distinct constructs. It appears, however, that higher levels of physical activity during adolescence may lead to lower increase in sedentary time during emerging adulthood. This could be due to physical activity levels tracking into adulthood and competing with sedentary time (Hallal, Victora, Azevedo, & Wells, 2006; Pearson et al., 2014). Given the lack of longitudinal studies looking at the relationship between BMI, physical activity, and sedentary behavior, more research is needed to clarify the role of these factors in sedentary behavior change.

Employment status. It was hypothesized that those who are not working would have a greater increase in sedentary behavior. This hypothesis was supported as those who were neither working nor in school, as well as those who were in school alone, experienced greater increases in sedentary behavior from ages 19 to 23. These findings were in line with those reported from several cross-sectional studies where individuals who were unemployed spent more time watching television (Rhodes et al., 2012). This could be due to the fact that these individuals have time available to engage in more sedentary activities. In addition, Individuals who are employed may need to dedicate a greater proportion of their day to job related tasks. Although more research is needed to determine how employment status relates to sedentary behavior change, the results from this study suggest that those who are unemployed are more likely to be more sedentary. As high levels of sedentary behavior are associated with adverse outcomes, it would be interesting to see whether years of unemployment serves as a moderator for this relationship.

Bioecological model. The bioecological model (Bronfenbrenner & Morris, 2006) can be used as a framework to understand the findings in the current study. This model consists of four interrelated and dynamic components that interact to affect development of an outcome. These components are process, person, context (i.e., environment), and time. Process represents the core of the model and includes proximal processes, which are interactions between humans and their environment (e.g., other persons, objects, or symbols) that occur over an extended period of time (Bronfenbrenner & Morris, 2006). Proximal processes are hypothesized to drive human development, but the extent to which they do so varies depending on the person, their environment and the time period that the processes take place. Examples of proximal processes include parent-child interactions, learning a new skill, problem solving, and acquiring new information (Bronfenbrenner & Morris, 2006).

The person component includes biological/genetic factors relating to the individual and consists of three characteristics: force, resource, and demand. Force characteristics involve those that relate to temperament, motivation, and related factors. Resource includes factors such as past experiences, material resources (e.g., housing, educational opportunities, caring parent), skills, and intelligence (Tudge, Mokrova, Hatfield, & Karnik, 2009). Demand characteristics, on the other hand, are more apparent and include aspects such as age, gender, and physical appearance.

The third component of the model is context or environment, which includes the microsystem, mesosystem, exosystem, and macrosystem. Briefly, the microsystem represents patterns of activities and interpersonal relations that the developing individual experiences in an environment, such as the home, school, or neighborhood. The mesosystem refers to the interrelations among the microsystems and the exosystem involves environments that have an indirect influence on the developing person (e.g., parent’s workplace). In addition, the macrosystem influences and is influenced by the other systems, and encompasses any group (e.g., culture or subculture) where members share values, beliefs, resources, opportunities, and lifestyles. Lastly, the time component refers to changes relating to the developing person's environment that occur. It also focuses on the duration of proximal process episodes, the frequency of these episodes across larger time intervals such as weeks or months, and the changing events and expectations across generations.

Given the various components of the bioecological model, it is evident that it considers how biological/genetic, social, environmental, and cultural influences interact to affect behaviors at various ages and developmental stages. The significant predictors of sedentary behavior change in this study suggest that measures of the process, person, environment, and time components impacted sedentary behavior change. Parental limits on screen time served as an assessment of proximal process, and race/ethnicity, perception of neighborhood safety, physical activity, and employment status were indicators of the person component. In addition, perception of neighborhood safety was a marker of the environment component. The longitudinal nature of the study addressed the time component by allowing the impact of the process, person and environment component of sedentary behavior change to be assessed.

Of the variables that were associated with sedentary behavior change, two are potentially modifiable – parental limits on screen time and physical activity. Targeting these factors from the process and person components in interventions may prove beneficial in curbing sedentary time. In addition, the finding that parental limit was associated with change in adolescence, and physical activity in emerging adulthood, suggests that these may be important factors to focus on during these developmental periods. Although more research is needed to confirm that parental limits relate to sedentary behavior change, the consistent findings from previous studies suggest that parental limits may lead to promising results.

One study showed that children (ages 9 to 15 years), whose parents had limits on how much television they watched, were less likely to exceed recommendations for screen time (Carlson et al., 2010). In addition, the lowest prevalence of exceeding recommendations for screen time was observed among parents who were consistent in setting rules and whose children were aware of the rules (Carlson et al., 2010). Results from another study supported this observation and highlighted the importance of setting specific and clear rules (Ramirez et al., 2011). Thus, providing recommendations to parents on how to set limits and the most effective means of doing so may be an important component to incorporate into sedentary behavior interventions.

In terms of (emerging) adults, few studies have focused on interventions to reduce their sedentary time. However, prior research suggests that incorporating a physical activity component into interventions may lead to reductions in sedentary activities (Biddle et al., 2011; Owen et al., 2011). Since decreases in sedentary behavior may not necessarily lead to increases in physical activity (Pearson et al., 2014), these interventions should explicitly specify other activities that can serve as a substitute for sedentary time (Owen et al., 2011).

Limitations and Future Directions

Although this study had novel findings, it had several limitations. While the role of several factors on sedentary behavior change was investigated, these variables only represented a small portion of the possible influences on sedentary time. In addition, some of these factors were not modifiable (e.g., race/ethnicity, gender) and most measured the person component of the bioecological model. Examining modifiable indicators of the person component may lead to the identification of targets for sedentary behavior interventions. One potential measure could be self-efficacy (i.e., confidence to reduce sedentary time) since adolescents with high levels of self-efficacy have been shown to have a lower chance of spending more than 4 hours a day in sedentary activities than those with low levels (Norman et al., 2005). Depressive symptoms is another factor that could be examined given studies showing that it is associated with sedentary behavior in adolescents (Van der Horst et al., 2007) and adults (Rhodes et al., 2012).

Since proximal processes are posited to play an important role in development (Bronfenbrenner & Morris, 2006), inclusion of other measures that assess this component may help to identify additional predictors of sedentary behavior change. For example, family support (Norman et al., 2005) and less positive parental relationships (Willoughby, 2008) may be useful measures of proximal processes to examine with respect to sedentary behavior. Other potential measures are peer relationships and peer involvement in sedentary activities. Previous studies suggest that a friend's sedentary behavior may relate to that of the individual's (Sawka, McCormack, Nettel-Aguirre, Hawe, & Doyle-Baker, 2013), however, null findings have been observed (Springer, Kelder, & Hoelscher, 2006).

Evaluating additional indicators from the environment component of the model, such as neighborhood walkability (Owen et al., 2011) and having a television in one's room (Salmon et al., 2011), may expand our understanding of the role of these factors on sedentary behavior change. Most cross-sectional studies examining neighborhood environmental attributes found that factors such as walkability and crime were generally not associated with sedentary behavior, although a few studies did report significant associations (Koohsari et al., 2015). Using the bioecological model as a framework, future studies should examine whether and how context and other modifiable factors influence sedentary behavior change. Such research could facilitate the development of interventions by highlighting factors that can be targeted to enhance reductions in sedentary time.

Another limitation is that participants self-reported their sedentary behavior and physical activity. As several studies have noted, this may lead to biased estimates of these behaviors. For instance, self-report of physical activity may result in overestimations of time spent in this behavior (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2009). Similarly, self-report measures of sedentary time may also be susceptible to recall bias and socially desirable responding (Lubans et al., 2011). While the use of accelerometers is often recommended as a means of addressing these limitations, they provide no insight into the types of sedentary behaviors in which participants are engaging. As a result, accelerometers are more appropriate examining total sedentary time. In light of this, future studies examining sedentary behavior and change in this outcome would benefit from using both subjective and objective measures to derive accurate information about how adolescents and emerging adults spend their sedentary time.

Since this study involved the secondary use of previously collected data, only three types of sedentary activities could be evaluated. The limited number of items available may have resulted in the low internal consistency reliability observed. As such, including other items related to sedentary behavior could augment the magnitude of the correlations among items and improve internal consistency. Focusing on additional activities, such as sitting while socializing and sitting while using a tablet or cell-phone, may also provide more insight into how and which sedentary behaviors are changing over time. More validated, reliable, and domain-specific self-report measures would need to be developed, however, to ensure that sedentary time is captured as accurately as possible (Marshall & Ramirez, 2011).

As this was the first study to examine the trajectory of sedentary behavior from adolescence to emerging adulthood using LGM, more research is also needed to determine whether these findings are replicable. In addition, future studies should determine how changes in sedentary behavior relate to risk of adverse health outcomes in adulthood. Growth mixture modeling could also be used to investigate whether there are different trajectories of sedentary behavior change during adolescence and emerging adulthood to determine whether there are groups of adolescents who maintain high levels of sedentary behavior over time.

Strengths

This study had a few notable strengths. First, the cohort-sequential approach and use of LGM allowed for the testing of the sedentary behavior trajectory from age 13 to 23 on a nationally representative sample of US adolescents. Given the limitations of previous studies, this study design and outcomes addressed a few important gaps in the literature. In particular, previous studies focused primarily on change during adolescence and often used a cross-sectional approach to examine sedentary time. In addition, most of the longitudinal studies were conducted outside of the US and others only assessed sedentary behavior on two separate occasions.

This study also adds to the existing literature by identifying factors associated with sedentary behavior change. Only gender and parental education were previously identified as predictors since other studies focused primarily on examining correlates. As such, the findings observed provide insight into factors that may be important when designing interventions to reduce sedentary time. More research is essential, however, to identify other modifiable variables to target. This would be a beneficial endeavor given the high levels of sedentary behavior observed among adolescents and emerging adults.

Conclusion

In summary, results from this study suggested that sedentary behavior decreased during adolescence and increased during emerging adulthood. From age 13 to 18, perception of neighborhood safety and parental limits on screen time played a role in adolescents' sedentary behavior changes. As they transitioned into emerging adulthood, race/ethnicity (being African American and Asian American) and more bouts of physical activity contributed to lower rates of increase in sedentary behavior. On the other hand, employment status (being in school only and not working and not in school vs working only) contributed to greater rates of increase in participants' reported sedentary time. Given the high levels of sedentary behavior observed during adolescence and emerging adulthood, effective means of reducing sedentary time are needed. Targeting parental limits on screen time and physical activity, modifiable factors from the process and person components of the bioecological model, may help to curb this behavior. More research is needed, however, to identify other variables that may play a role in adolescents' and emerging adults' sedentary activities.

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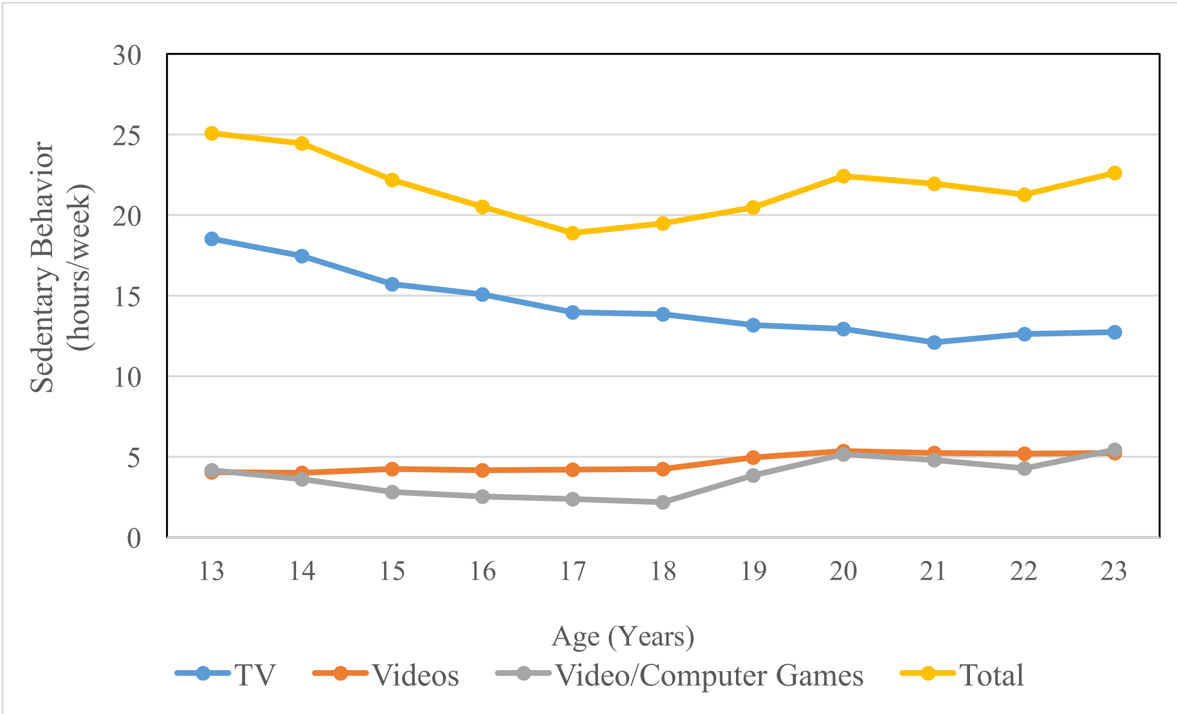

Figure 1

Graph of average time spent in total sedentary behavior, television viewing, video viewing, and playing video/computer games from ages 13-23 years.

Table 1

Sample characteristics[a]

Gender (%)	
Boys	48.19
Girls	51.81
Age (mean, SE)	15.07 (.10)
Race/ethnicity (%)	
Non-Hispanic white	67.40
Hispanic	10.76
African American	14.82
Native American	4.01
Asian	3.3
Feel safe in neighborhood (%)	
Yes	90.00
No	10.00
Parental limits on TV viewing (%)[b]	
Limits on how much TV watched	19.59
Limits on which TV programs watched	24.55
Household income (Mean, SE)[c]	47.46 (2.27)
Parental education (%)	
Less than high school	12.80
High school/GED	30.40
Some college	28.90
College or > 4 years	27.90
Body mass index (kg/m^2; mean, SE)	22.35 (.14)
Physical activity (mean, SE)[d]	6.27 (.10)
Employment status (%)	
Working only	46.46
In school only	11.40
Working and in school	27.35
Not working and not in school	14.46

Note. [a]Descriptives are based on Wave I data, except for employment status, which was examined at Wave III. Estimates are weighted for national representation and standard errors are corrected for cluster sampling. [b] Responses indicate the percentage of participants who indicated that their parents let them decide how much TV and which TV programs they watched. [c]SE = standard error; income in thousands. [d]Physical activity = bouts of moderate to vigorous physical activity per week.

Table 2

Means and standard errors for sedentary behavior from ages 13-32 years[a]

Age	**Mean**[b]	**Standard Error**
13	25.07	1.56
14	24.43	0.94
15	22.16	0.83
16	20.52	0.69
17	18.89	0.74
18	19.48	0.81
19	20.45	0.78
20	22.41	0.80
21	21.96	0.86
22	21.27	0.68
23	22.62	0.74
24	23.64	1.24
25	26.59	2.41
26	14.98	0.86
27	15.48	0.63
28	14.48	0.67
29	16.05	0.67
30	16.72	0.68
31	17.53	1.13
32	17.30	2.01

Note. [a]Estimates are weighted for national representation and standard errors are corrected for cluster sampling. [b] From ages 13-25, total hours/week based on time spent watching TV and videos, and playing video/computer games. Total sedentary time from ages 26-32 was calculated using two questions: total hours/week watching television or videos and total hours playing video or computer games or using a computer.

Table 3

Unstandardized parameter estimates for piecewise growth model examining predictors of initial levels of sedentary behavior at age 13 (intercept)

	Estimate	*p*	*95% Confidence Interval*
Intercept	**24.99**	**<.001**	**[23.11, 26.89]**
Predictors of the Intercept			
Gender (ref = girls)	**6.47**	**<.001**	**[4.05, 8.90]**
Parental education (ref = college or > 4 years)			
Less than high school	5.96	.08	[-.76, 12.68]
High school/GED	2.34	.21	[-1.32, 6.01]
Some college	-.87	.60	[-4.09, 2.35]
Parental limits on television viewing (ref = no limits) [a]	**-5.50**	**.001**	**[-8.76, -2.24]**
Household income	**-.03**	**.045**	**[-.05, -.001]**
Feel safe in neighborhood (ref = no)	**-11.97**	**.001**	**[-19.25, -4.70]**
Race/ethnicity (ref = non-Hispanic whites)			
Hispanic	4.92	.06	[.-.11, 9.95]
African American	4.88	.10	[-.95, 10.71]
Native American	6.34	.29	[-5.46, 18.13]
Asian	-4.29	.19	[-10.65, 2.06]
Body mass index (kg/m^2)	**.56**	**.001**	**[.23, .89]**
Physical activity (bouts/week)[b]	-.30	.16	[-.73, .12]

Note. [a] Parental limits on screen time: Whether parents let participants decide how much TV and which TV programs they watched. Reference group refers to participants whose parents let them make their own decisions. [b]Physical activity = bouts of moderate to vigorous physical activity per week. Significant estimates are in bold.

Table 4

Unstandardized parameter estimates for piecewise growth model examining predictors of sedentary behavior change from ages 13-18 years (slope)

	Estimate	*p*	*95% Confidence Interval*
Slope	**-1.27**	**<.001**	**[-1.76, -.78]**
Predictors of the Slope			
Gender (ref = girls)	-.49	.19	[-1.21, .24]
Parental education (ref = college or > 4 years)			
Less than high school	-.72	.47	[-2.65, 1.21]
High school/GED	-.19	.71	[-1.18, .80]
Some college	.38	.43	[-.54, 1.29]
Parental limits on television viewing (ref = no limits) [a]	**1.22**	**.02**	**[.20, 2.25]**
Household income	-.002	.53	[-.004, .008]
Feel safe in neighborhood (ref = no)	**2.70**	**.01**	**[.78, 4.62]**
Race/ethnicity (ref = non-Hispanic whites)			
Hispanic	-.89	.21	[-2.30, .52]
African American	1.47	.06	[-.07, 3.00]
Native American	-1.41	.49	[-5.44, 2.61]
Asian	**2.27**	**.02**	**[.36, 4.18]**
Body mass index (kg/m^2)	-.08	.12	[-.17, .02]
Physical activity (bouts/week)[c]	.10	.10	[-.02, .21]

Note. [b] Parental limits on screen time: Whether parents let participants decide how much TV and which TV programs they watched. Reference group refers to participants whose parents let them make their own decisions. [c]Physical activity = bouts of moderate to vigorous physical activity per week. Significant estimates are in bold.

Table 5

Unstandardized parameter estimates for piecewise growth model examining predictors of the sedentary behavior change from ages 19 to 23 years (slope)

	Estimate	*p*	*95% Confidence Interval*
Slope	**.39**	**<.001**	**[.28, -.56]**
Predictors of the Slope			
Gender (ref = girls)	.13	.36	[-.14, .39]
Parental education (ref = college or > 4 years)			
Less than high school	-.23	.47	[-.84, .39]
High school/GED	.09	.61	[-.25, .42]
Some college	-.14	.39	[-.46, .18]
Parental limits on television viewing (ref = no limits) [a]	-.40	.06	[-.82, .02]
Household income	.001	.26	[-.001, .002]
Feel safe in neighborhood (ref = no)	-.35	.17	[-.84, .15]
Race/ethnicity (ref = non-Hispanic whites)			
Hispanic	-.25	.34	[-.78, .27]
African American	**-1.13**	**<.001**	**[-1.62, -.63]**
Native American	-.97	.13	[-2.24, .30]
Asian	**-.67**	**.049**	**[-1.34, -.003]**
Body mass index	.01	.69	[-.03, .05]
Physical activity (bouts/week)[b]	**-.04**	**.03**	**[-.07, -.003]**
Employment status (ref = working only)[c]			
In school only	**.43**	**.01**	**[.11, .75]**
Working and in school	-.13	.14	[-.30, .04]
Not working and not in school	**.91**	**<.001**	**[.55, 1.28]**

Note. [a] Parental limits on screen time: Whether parents let participants decide how much TV and which TV programs they watched. Reference group refers to participants whose parents let them make their own decisions. [b]Physical activity = bouts of moderate to vigorous physical activity per week. Significant estimates are in bold. [c]Employment status was measured at Wave III.