Archives of Business Research – Vol.7, No.7
Publication Date: July. 25, 2019
DOI: 10.14738/abr.77.6821.
Son, C. H. (2019). Life Course Effects of Adverse Childhood Experiences on Health-Related Quality of Life. *Archives of Business Research,* 7*(7),* 320-337.

Life Course Effects of Adverse Childhood Experiences on Health-Related Quality of Life

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ABSTRACT

This study examines the duration of the effects of adverse childhood experiences (ACEs) on health-related quality of life (HRQOL) throughout the lifespan with the adult population by five age groups. The study conducts a cross-sectional regression analysis using the 2012 Behavioral Risk Factor Surveillance System (BRFSS) data. In the empirical results, the estimated coefficients of all ACE scores for the mentally unhealthy days exceed the coefficients for the physically unhealthy days in all age groups. It suggests that the adverse effects of ACEs on mental health outcomes are more significant than the effects of ACEs on physical health outcomes. In conclusion, the empirical results indicate that the adverse impacts of cumulative ACE scores on both physical and mental health outcomes are onset at the early stage of adulthood and persist into the late stage of life. Noticeably, the adverse effects slightly drop and rebound at the middle age group, ages 40-49, and then the adverse associations of ACEs on HRQOL remain throughout the life course.

Keywords: Health-Related Quality of Life, Physical Health, Mental Health, BRFSS, Adverse Childhood Experiences

INTRODUCTION

It has been reported that exposure to adverse childhood experiences (ACEs) is common and links to an increase in risks of lifetime diseases and to negative consequences of health outcomes. An earlier review of the literature by Corso, et al. (2008) revealed that ACEs were significantly associated with persistence of a variety of health problems across the life span because ACEs increased the risk of health-related behavioral problems over the life course. As a result, ACEs could lead to significant economic costs in the form of lost work productivity and health care spending (Monnat and Chandler, 2015). The study (Fang, et al., 2012) addressed that the total lifetime economic burden resulting from child abuse and neglect in the United States was approximately $124 billion in 2010 dollars; the study (Gelles and Perlman, 2012) approximated the cost of child maltreatment would be $80 billion in 2012 dollars. The average lifetime cost per victim of ACEs would consist of criminal justice costs, special education costs, child welfare costs, short-term health care costs, long-term medical costs, and loss of productivity in the workplace. The ACEs are significantly associated with such adverse health effects and social economic costs, but they are preventable.

Studies (Anda, et al., 2006; Danese, et al. 2007; Iniguez and Stankowski, 2016; Bellis, et al., 2017) reported that ACEs could lead to toxic stress when there was strong, frequent, or prolonged activation of the stress-response system in the body develops without the buffering protection of a supportive adult relationship. The biological reaction to toxic stress could be incredibly destructive and could last a lifetime. The studies also described the process of developing from ACEs to the risks of health in adulthood – chronic childhood stressors, such as abuse and behavior-related adverse experiences could cause enduring brain dysfunction that impacts adversely cognitive functions. Put differently, childhood trauma links to a variety of changes in brain structure and function, and childhood stressors lead to long term changes in multiple brain circuits and system. Consequently, stressful or traumatic childhood experiences affect health behavioral problems and quality of life throughout the lifespan. For instance,

these associations were substantial: more than 30% of adults who suffer mental disorders are directly related to childhood adversities (Afifi, et al., 2008; Green, et al., 2010). This extensive range of the effects of ACEs on mental health suggests that it might influence victims' long-term health-related quality of life (HRQOL) (Corso, et al., 2008). The HRQOL is defined as a multidimensional assessment of well-being and health status, and it measures an individual's self-perceptions of general health, such as physical health, mental health, and social functioning (Jayasinghe, et al., 2016; Yadav, et al., 2016). HRQOL is a strong indicator of overall health, future disability, morbidity, and mortality (Gandhi, et al., 2015; Yin, et al., 2016; Garey, et al., 2017).

Such previous studies suggested that the effects of ACEs were negatively associated with health outcomes throughout the lifespan. Majority of the studies examined the effects of ACEs on the health outcomes of the entire adult population aged 18 or older. Meanwhile, studies (Clark, et al., 2007; Corso, et al., 2008; Benjet, et al., 2010; Clark, et al., 2010; McLaughlin, et al., 2010; Roh, et al., 2015) investigated the association of ACEs with health outcomes by specific age groups to examine the impact of ACEs at a stage of life, and the studies found significant results. However, the empirical results were not sufficient enough to provide evidence that the effect of the ACEs persisted to which stage of the life courses. Especially, no studies have investigated the effect of ACEs on HRQOL at all stages of the life course. Although an early study by Son (2016) revealed that the ACEs had a significant association with HRQOL in adulthood, the empirical results still were inconclusive for the persistence of the adverse effect of ACEs on HRQOL throughout the lifespan. To support the previous literature, this study extends the early researches by adding and examining the negative health effects of ACEs by five stages of the life course (18-29; 30-39; 40-49; 50-59; and 60 or older) to clarify the persistence of the adverse effects of ACEs on HRQOL.

The data for this study are obtained from 2012 Behavioral Risk Factor Surveillance System (BRFSS), a large-scale national health survey collected by the Centers for Disease Control and Prevention (CDC) in the United States. The BRFSS is a surveillance system operated by the state health departments in collaboration with the CDC. The details of the BRFSS are described in section 3. HRQOL, one of the core modules in the BRFSS questionnaires, has questions to monitor both self-reported physically and mentally unhealthy days. The number of physically/mentally unhealthy days as a measure of the HRQOL is a dependent variable in the analytical models. The adverse childhood experience module was optional in the 2012 BRFSS questionnaire. Only five states (Iowa, North Carolina, Oklahoma, Tennessee, and Wisconsin) implemented the ACEs module. All explanatory variables are also taken from the 2012 BRFSS, including socio-demographic variables and health behavioral variables.

ANALYTICAL FRAMEWORK

HRQOL is an outcome measure of an individual's self-rated perception of overall quality of life and consists extensively of physical health, mental health, social functioning, health-related symptoms, and activity of daily living. The primary determinants of HRQOL in public health research are widely examined, including chronic health problems and health conditions: diabetes, cardiovascular diseases, insulin use, alcohol and drug abuse, depression and suicide, hypertension, diabetes, anxiety disorders, etc. (Jayasinghe, et al., 2016; Yadav, et al., 2016). Health-related literature has, especially, pointed to socio-demographic factors, such as marital status, employment, income, wealth, and education as the fundamental factors (Braveman and Gottlieb, 2014; Meyer, et al., 2014; Tchicays and Lorentz, 2016). Thus, the production function of health is developed:

$$H = h(d, z) \quad (1)$$

where 'H' denotes health outcomes. 'd' represents other relevant factors of health outcomes, mainly socio-demographic factors (marital status, employment status, income level, race/ethnicity, age, educational level, and gender), ACEs, and state dummy variables. 'z' represents an individual's health problems and conditions. However, to observe an individual's true chronic health problems and conditions is practically infeasible. Previous studies (Dey, et al., 2013; Yadav, et al., 2016; Truthmann, et al., 2017) reported that there was a strong association of health behavioral factors with the chronic health problems and health conditions. Thus, this study takes the health behavioral factors as proxies for individuals' health problems and conditions and then substitutes the health-risk behavioral factors for the individual's health problems and conditions in health production function (1). The function becomes:

$$H = h(d, m) \qquad (2)$$

where 'm' represents health behavioral variables: Body Mass Index (BMI), smoking status, alcohol consumption, and exercise. Since the number of unhealthy days as a measure of HRQOL is the dependent variable, the basic econometric model (Ruhm, 2003; Ruhm, 2005) is the following:

$$H_{ij} = \beta_0 + x_{ijk}\beta_k + S_j\beta_j + u_{ij} \qquad (3)$$

where H_{ij} denotes the number of physically and mentally unhealthy days during the past 30 days for individual *i* in state *j*. The number of unhealthy days ranges from 0 to 30 with a logical maximum of 30 unhealthy days per month (Jia and Lubetkin, 2009; Clifford, et al., 2013; Mahabaleshwarkar, et al., 2013; Son, 2016). x is a vector of personal characteristics, including demographic variables, health behavioral variables, and adverse childhood experiences; and S is a state fixed-effect. β_0 is a fixed non-random constant; β_k is a coefficient matrix of the equation with a dimension k x 1 where k represents the number of explanatory variables; and β_j is a coefficient of four states. u_{ij} is an error term of observation *i* in state *j* and an independent random variable with zero mean and constant standard error σ_u. It is generally assumed that Cov (x_{ijk}, u_{ij}) = 0 (Mesbah, 2004; Jia and Lubetkin, 2009; Son and Lee, 2014). With expected value of u_{ij}, E(u_{ij}) = 0, the conditional expected value of dependent variable is:

$$E(H_{ij}|x_{ijk}) = \beta_0 + x_{ijk}\beta_k + S_j\beta_k \qquad (4)$$

This state fixed effect model holding constant differences across states removes the effects of differences associated with other relevant independent variables among states on the dependent variables and captures the effects of unobserved state-specific variables. For instance, residents in high- or low-income states may have different profiles of health risk factors. Also, people who live in low-income states are likely to exhibit a lower level of demand for medical and healthcare services than people who live in high-income states because the medical and healthcare services are, in general, defined as normal goods in economics.

Table 1: Definition, mean, and standard deviations of variables[a]

Variable	Definition	Mean	SD
Unhealthy Days			
PHYSHLTH	Number of days when physical health was not good during the past 30 days.	3.784	8.271
MENTHLTH	Number of days when mental health was not good during the past 30 days.	3.667	8.006
Socio-Demographic Variables			
Married	Dichotomous variable that equals 1 if respondent is married.	0.558	0.497
Employed	Dichotomous variable that equals 1 if respondent is employed for wages or self-employed.	0.604	0.489
Male	Dichotomous variable that equals 1 if respondent is male.	0.508	0.500
Less HS	Dichotomous variable that equals 1 if respondent did not graduate high school.	0.117	0.321
HS	Dichotomous variable that equals 1 if respondent graduated high school.	0.301	0.459
Some college	Dichotomous variable that equals 1 if respondent attended college or technical school, or respondent graduated from college (college 4 years or more).	0.583	0.493
Income25	Dichotomous variable that equals 1 if respondent's annual household income < $25,000.	0.296	0.457
Income2550	Dichotomous variable that equals 1 if $25,000 ≤ respondent's annual household income < $50,000.	0.281	0.450
Income5075	Dichotomous variable that equals 1 if $50,000 ≤ respondent's annual household income < $75,000.	0.164	0.370
Income75+	Dichotomous variable that equals 1 if respondent's annual household income ≥ $75,000.	0.259	0.438
Other Races	Dichotomous variable that equals 1 if respondent is not White or Black.	0.093	0.290
White	Dichotomous variable that equals 1 if respondent is White, but not Hispanic.	0.791	0.407
Black	Dichotomous variable that equals 1 if respondent is Black, but not Hispanic.	0.117	0.321
Health Behavioral Variables			
Normal weight	Dichotomous variable that equals 1 if respondent is normal weight (18.50 ≤ BMI[b] < 25.00).	0.311	0.463
Underweight	Dichotomous variable that equals 1 if respondent is underweight (BMI[b] < 18.50).	0.014	0.118
Overweight	Dichotomous variable that equals 1 if respondent is normal weight (25.00 ≤ BMI[b] < 30.00).	0.365	0.481
Obese	Dichotomous variable that equals 1 if respondent is obese (30.00 ≤ BMI[b]).	0.310	0.462
Current smoker	Dichotomous variable that equals 1 if respondent now smokes cigarettes every day or some days.	0.213	0.410
Current drinker	Dichotomous variable that equals 1 if respondent had at least one drink of alcohol in the past 30 days[c].	0.530	0.499
Current Exercise	Dichotomous variable that equals 1 if respondent participates in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise during the past month.	0.771	0.420

Notes: a. Means and Standard Deviations (SD) are weighted by the BRFSS sample weight factor. All means are statistically significant using two tailed t-test with 95% confidence interval. b. Body Mass Index (BMI): weight (kg) divided by square of height (meter). c. One drink is equivalent to a 12-ounce beer, a 5-ounce glass of wine, or a drink with one shot of liquor.

EMPIRICAL IMPLEMENTATION

The data are drawn from the 2012 BRFSS, a collaborative project of the CDC and state health departments. The BRFSS is an ongoing data collection program designed to measure behavioral risk factors for the adult population living in households through monthly landline-telephone and cellular-telephone-based surveys. The BRFSS operations are managed by state health departments that follow the guidelines provided by the CDC. Some states from the beginning stratified population are allowed to collect region-wise data in their own states. The BRFSS questionnaire consists of three parts: a core component as a standard set of questions asked by all states, optional modules supported by the CDC as a set of questions on specific topics that states elect to use on their questionnaires, and state-added questions as questions developed or acquired by participating states which are added to their questionnaires. The

state health department and the CDC agree on the content of the core component and optional modules each year. The BRFSS guidelines specify that all states execute the core component questions without modification, but states may choose to add any, all, or none of the optional modules. The adverse childhood experience module in 2012 BRFSS was optional. Only five states (Iowa, North Carolina, Oklahoma, Tennessee, and Wisconsin) implemented the ACEs module. The total baseline observations for the five states were 39,434. This study excludes observations with missing values, unanswered questions, don't know/not sure, questions not asked, and refusals. 22,987 (58.29%) of survey participants completed all questions pertaining to perceived numbers of physically/mentally unhealthy days, socio-demographic and health behavior variables, and ACEs. Descriptions and summary statistics of unhealthy days, socio-demographic variables, and health behavioral variables are shown in Table 1, and ACE variables are presented in Table 2.

Table 2: Definition, mean, and standard deviations of self-reported each of eight categories of adverse childhood experiences and ACE scores

Variable	Definition	Mean and S.D.
Adverse Childhood Experiences		
Physical abuse	Dichotomous variable that equals 1 if a parent or adult ever hit, beat, kick, or physically hurt the respondents once or more than once in any way, not including spanking before age 18.	0.149 (0.356)
Emotional abuse	Dichotomous variable that equals 1 if a parent or adult ever swear at the respondent, insult the respondent, or put the respondent down once or more than once.	0.326 (0.469)
Sexual abuse	Dichotomous variable that equals 1 if anyone at least 5 years older than the respondent or an adult ever touch the respondent sexually/try to make the respondent touch them sexually/force the respondent to have sex once or more than once.	0.108 (0.311)
Mental Illness	Dichotomous variable that equals 1 if respondent live with anyone who was depressed, mentally ill, or suicidal.	0.164 (0.370)
Substance abuse	Dichotomous variable that equals 1 if respondent live with anyone who was a problem drinker or alcoholic/who used illegal street drugs or who abused prescription medications.	0.272 (0.445)
Incarceration	Dichotomous variable that equals 1 if respondent live with anyone who served time or was sentenced to serve time in a prison, jail, or other correctional facility.	0.080 (0.272)
Separation/divorce	Dichotomous variable that equals 1 if respondent's parents were separated or divorced.	0.273 (0.445)
Domestic violence	Dichotomous variable that equals 1 if parents or adults in the respondent's home ever slap, hit, kick, punch or beat each other up once or more than once.	0.170 (0.375)
ACE Scores		
ACE0	Dichotomous variable that equals 1 if the total number of ACEs respondent reported equals 0.	0.390 (0.488)
ACE1	Dichotomous variable that equals 1 if the total number of ACEs respondent reported equals one.	0.242 (0.428)
ACE2	Dichotomous variable that equals 1 if the total number of ACEs respondent reported equals two.	0.127 (0.333)
ACE3	Dichotomous variable that equals 1 if the total number of ACEs respondent reported equals three.	0.087 (0.282)
ACE4	Dichotomous variable that equals 1 if the total number of ACEs respondent reported equals four.	0.062 (0.240)
ACE5+	Dichotomous variable that equals 1 if the total number of ACEs respondent reported equals five or more.	0.092 (0.290)

Notes: Standard deviations (S.D.) are in parentheses. Means and Standard Deviations are weighted by the BRFSS sample weight factor. All means are statistically significant using two tailed t-test with 95% confidence interval.

Health-related quality of life

The measure of HRQOL in the health day module was about the number of poor physical health days and poor mental health days in the past 30 days. Physical health status was measured by the question about the presence of any activity limitation resulting from an impairment or health problem: "Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good?" Mental health status was measured by the question: "Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?" These two measures are served as outcome variables of HRQOL. The number of unhealthy days ranges from 0 to 30 with a logical maximum of 30 unhealthy days per month. The measures of HRQOL scale in the BRFSS have been tested and established for their validity and reliability in the previous studies (Anderson, et al., 2003; Brown, et al., 2004; Evenson and McGinn, 2005; Kapp, et al., 2009) and have been widely used in public health studies.

Clinicians and clinical researchers often use the 14-day minimum period as a marker for poor health conditions during the past 30 days. Studies (Ford, et al., 2008; Heath and Brown, 2009; Chen, et al., 2011; Mahabaleshwarkar, et al., 2013; Gandhi, et al., 2015) constructed the numbers of unhealthy days into two mutually exclusive categories using 14 days or more as the cutoff value for determining the chronic presence of physical or mental problems. Another study by Clifford, et al. (2013) dichotomized the unhealthy days into no unhealthy days per month (none) versus one or more unhealthy days (1-30) per month. However, setting any cut-off value or the threshold of 14 days or more in the study could be problematic. Hypothetically, a survey participant with zero unhealthy days during the past 30 days is indifferent in the empirical analysis from a participant with 13 unhealthy days if a study sets a cutoff value. Because of this solicitude, this study accounts the number of unhealthy days as a continuous measure (Jia and Lubetkin, 2009; Zullig and Hendryx, 2010; Horner-Johnson, et al., 2010). Thus, participants reported the more unhealthy days during the past month as the poorer the HRQOL. The average numbers of unhealthy days from 2012 BRFSS survey due to poor physical and poor mental health are 3.784 days and 3.667 days respectively per month (Table 1). 64.73%, 69.55%, and 51.02% (not shown in the tables) of participants did not have any unhealthy day because of poor physical, poor mental, and both poor physical and mental health problems respectively.

Explanatory variables

Socio-demographic variables are married, employed, male, education level, income level, and race/ethnicity. Health behavioral variables are body mass index, current smoker, current drinker, and current exercise. These variables are widely used in HRQOL studies (Mahabaleshwarkar, et al., 2013; Braveman and Gottlieb, 2014; Meyer, et al., 2014). The means and standard deviations are shown in Table 1.

The socio-demographic variables: There are six categories of marital status: married, divorced, widowed, separated, never married, and a member of an unmarried couple. The current study examines the effect of ACEs on HRQOL for married participants by setting the effect of ACESs on HRQOL for other marital statuses as a reference. 55.8% of respondents reported being married. The study (Jayasinghe, et al., 2016) on the impact of lifestyle risk factors on HRQOL suggested that employment status was a significant predictor of physical and mental health outcomes. The study also reported that the level of educational attainment was positively associated with physical health. In the demographics module of the BRFSS questionnaire, there were eight mutually exclusive categories of employment status, such as employed for wages, self-employed, out of work for more than 1 year, out of work for less than

1 year, a homemaker, a student, retired, and unable to work. This study sets employed for wages or self-employed as employed. 60.49% of respondents were employed for wages or self-employed. 50.8% of survey participants in the five states were males. Three levels of education are examined: less than high school graduation, high school graduate, and some college or higher degree graduate. 11.7%, 30.1%, and 58.3% of respondents reported their education level as less than high school, high school graduate, and some college respectively.

Individuals in lower-income areas may have lower access to health care due to health care disparities, such as geographical mal-distribution of physicians in rural and lower-income areas. If this is ruled out, high-income individuals might be likely to exhibit a higher level of demand for medical and health services than low-income individuals since medical and health services are, in general, assumed to be normal goods. The higher level of consumption of medical and health services is positively associated with improvements in HRQOL if everything else held constant. The BRFSS asked participants for their annual household income from all sources with eight categorical income levels from less than $25,000 to $75,000 or more. This study re-categorizes income levels into four levels. 29.6% of participants reported an annual household income of less than $25,000 in 2012, and 25.9% of participants reported an annual household income of $75,000 or more. Survey participants were also asked for race/ethnicity. Studies (Montgomery, et al., 2013; Simms, et al., 2013) investigated race-based health outcomes in adulthood. The results suggested that White, non-Hispanic were less likely to have physically and mentally unhealthy days than other races. This study uses three groups of the race/ethnicity: White, but not Hispanic; Black, but not Hispanic; and all other races. 79.1% of the BRFSS survey participants were White, non-Hispanic, and 11.7 % of participants were Black, but not Hispanic.

The health behavioral variables: In the BRFSS demographic module, survey participants were asked for their height and weight. Based on the height and weight, the CDC calculated and provided each participant's BMI which represented a relative weight for height. It is significantly correlated to the total volume of body fat. Four levels of BMI were reported in the calculated-variables module: normal weight, underweight, overweight, and obese. 31.1% of survey participants were normal weight, and 67.5% of them were overweight or obese. A current smoker was defined as a respondent who now smoked cigarettes every day or some days. 21.3% of the respondents were current smokers. A current drinker was defined as a respondent had at least one drink of alcohol in the past 30 days. One drink was equivalent to a 12-ounce beer, a 5-ounce glass of wine, or a drink with one shot of liquor. 53.0% of the respondents were current drinkers. The current exercise was defined as a respondent who participated in any physical activities or exercise other than her or his job-related regular activities during the past month including running, calisthenics, golf, gardening, or walking for exercise. 77.1% of survey respondents reported participating in any physical activities or exercises.

Adverse childhood experiences: The ACEs module consisted of eleven questions about events happened during a respondent's childhood which referred to the time period before the respondent became 18 years of age. Three of those questions were about sexual abuse: "How often did anyone at least 5 years older than you or an adult, ever touch you sexually?; …, try to make you touch them sexually?; and …, force you to have sex?" A response of either 'once' or 'more than once' to any of the above three questions was defined as sexual abuse. The substance abuse was combined with the following two abuse ACE questions: "Did you live with anyone who was a problem drinker or alcoholic?" and "Did you live with anyone who used illegal street drugs or who abused prescription medications?" As a result, the ACE questions

become a total of eight categories, such as three categories of child abuse (physical, emotional, and sexual) and five categories of household dysfunction (mental illness, substance abuse, incarnation, separation/divorce, and domestic violence). All ACE variables are dichotomized as one if a participant responded 'yes' to each question and answered either 'once' or 'more than once'. The prevalence of each experience and of the ACE scores is shown in Table 2.

Studies (Brown, et al., 2013; Chapman, et al., 2013; Mersky, et al., 2013) reported that the individual ACEs had been reported to be common and that the individual ACEs were highly interrelated to one another: when a respondent reported one ACE, the likelihood of reporting exposure to multiple ACEs increased significantly. For instance, in this study, the estimated correlation coefficients are 0.429 between physical abuse and emotional abuse and 0.440 between physical abuse and domestic violence. If the highly interrelated individual ACEs are in the same empirical model, a multiple regression model may give invalid results about any individual predictor or about which predictors are redundant with respect to others. Because of this concern, this study uses the ACE scores, known as a dosage effect, in the empirical models instead of the individual ACEs. Studies (Chartier, et al., 2010; Adam, et al., 2011) emphasized the importance of the dosage effect of ACEs on health outcomes. The studies concluded that the character of individual adverse experiences was not the most powerful predictor for physical and mental health outcomes in adulthood. Another study by Simms, et al. (2013) reported that the number of adverse experiences provided the most explanatory power in predicting physical and mental health rather than the specific character of individual ACE categories. Also, studies (Anda, et al., 2006; Bellis, et al., 2017) found that cumulative exposure to childhood abuse and household dysfunction had been linked to numerous poor health outcomes in adulthood.

To calculate the ACE scores, exposure to one category of ACEs was counted as 1 point toward the score. The point for each observation was summed to get the ACE scores which ranged from 0-8. A respondent who had a zero score was considered to have no ACE exposure. Six ACE scores (0, 1, 2, 3, 4, and 5+) were implemented in the analyses with the zero score serving as a reference. 61% of the respondents reported being exposed to at least one ACE, and 9.2% reported being exposed to five or more ACEs during childhood. The prevalence of each category of the ACEs ranged from 8% to 32.6%. The highly prevalent ACEs were emotional abuse (32.6%), separation/divorce (27.3%), and substance abuse (27.2%). The observations were excluded if participants answered "don't know/not sure" or "refused" for any ACE question.

ANALYSIS AND RESULTS

Descriptive analysis

The prevalence of both physically and mentally unhealthy days, individual adverse childhood experiences, and ACE scores by the age group is calculated with the BRFSS sample weighting factor (Table 3). The average number of physically unhealthy days increases as the age group rises: the average numbers of physically unhealthy days are 2.37, 2.45, 3.55, 4.77, and 5.04 for ages 18-29, ages 30-39, ages 40-49, ages 50-59, and age 60+ respectively. For mentally unhealthy days, in contrast, the age group 18-29 has the highest average number of mentally unhealthy days (4.13), and the age group 60+ has the lowest average number of mentally unhealthy days (2.48). Also, the age group 60+ has the lowest prevalence of each of the individual ACE categories. Importantly, the prevalence of emotional abuse, mental illness, incarceration, and separation/divorce categories increases as the age group rises. For the ACE scores, 52.3% of adults aged 60+ did not report experiencing any of the ACEs. The prevalence of ACE1 was similar across all age groups. The prevalence of ACE5 falls as the age group rises. Notably, 14% of respondents aged 18-29 had 5 or more adverse childhood experiences.

Table 3: Prevalence of unhealthy days, individual adverse childhood experiences and ACE scores by age group

	Age 18-29 (n=1993)	Age 30-39 (n=2794)	Age 40-49 (n=3682)	Age 50-59 (n=4957)	Age 60+ (n=9561)
Unhealthy Days					
PHYSHLTH	2.370 (5.889)	2.450 (6.289)	3.550 (7.904)	4.770 (9.444)	5.040 (9.688)
MENTHLTH	4.130 (8.067)	3.880 (7.855)	4.040 (8.398)	4.280 (8.832)	2.480 (6.914)
Adverse Childhood Experiences					
Physical abuse	0.158 (0.365)	0.174 (0.379)	0.174 (0.379)	0.159 (0.366)	0.102 (0.302)
Emotional abuse	0.392 (0.499)	0.374 (0.484)	0.366 (0.482)	0.335 (0.472)	0.215 (0.411)
Sexual abuse	0.105 (0.307)	0.111 (0.314)	0.134 (0.340)	0.127 (0.332)	0.077 (0.266)
Mental Illness	0.245 (0.430)	0.199 (0.399)	0.168 (0.374)	0.162 (0.368)	0.085 (0.279)
Substance abuse	0.301 (0.459)	0.308 (0.462)	0.288 (0.453)	0.288 (0.453)	0.204 (0.403)
Incarceration	0.150 (0.357)	0.120 (0.325)	0.076 (0.265)	0.053 (0.225)	0.031 (0.172)
Separation/divorce	0.405 (0.491)	0.381 (0.486)	0.304 (0.460)	0.213 (0.409)	0.134 (0.341)
Domestic violence	0.172 (0.378)	0.190 (0.392)	0.188 (0.391)	0.203 (0.402)	0.116 (0.320)
ACE Scores					
ACE0	0.323 (0.468)	0.317 (0.465)	0.334 (0.472)	0.391 (0.488)	0.523 (0.499)
ACE1	0.232 (0.422)	0.249 (0.432)	0.252 (0.434)	0.242 (0.428)	0.238 (0.426)
ACE2	0.134 (0.341)	0.133 (0.339)	0.147 (0.354)	0.120 (0.325)	0.109 (0.311)
ACE3	0.098 (0.297)	0.097 (0.296)	0.103 (0.303)	0.088 (0.283)	0.063 (0.242)
ACE4	0.073 (0.260)	0.083 (0.275)	0.061 (0.238)	0.064 (0.245)	0.039 (0.194)
ACE5+	0.140 (0.347)	0.122 (0.328)	0.105 (0.306)	0.095 (0.294)	0.029 (0.167)

Notes: Standard deviations (S.D.) are in parentheses. Means and Standard Deviations are weighted by the BRFSS sample weight factor. All means are statistically significant using two tailed t-test with 95% confidence interval.

Multiple regression results

The BRFSS provides the final weight factor to each observation. Without weighting factors in the empirical analysis, a researcher assumes that each observation has an equal probability of being selected and that non-coverage and non-response are equal among all segments of the population. When deviations from these assumptions significantly affect the results obtained from a data set, then weighting each observation can help to adjust for violations of the Ordinary Least Squares (OLS) assumption – the weighting minimizes potential bias and maximizes the generalizability of study findings to the population. However, the multiple regression estimates in this study are employed without the BRFSS weight factor because of the Disproportionate Stratified Sample (DSS) design for landline-telephone samples and random sample for cellular-telephone survey in the BRFSS. Using a similar data, previous studies (DuMouchel and Duncan, 1983; Chou, et al., 2004; Son and Lee, 2014; Son, 2016) also conducted an unweighted regression analysis due to the BRFSS stratification sampling method.

The primary determinants of health outcomes, such as chronic health problems and health conditions – diabetes, heart diseases, insulin use, etc. (Clifford, et al., 2013; Simms, et al., 2013), are not accounted in the empirical models since this study focuses on investigating the effects of mainly ACEs on HRQOL. The absence of the primary determinants of health outcomes in the empirical models affects the measures of the overall model fits with relatively lower R-squared scores between 4.2% and 24.93% (Tables 4 and 5). In addition, the observed values of the number of unhealthy days range from 0-30, but the predicted values could fall outside the meaningful range of zero to thirty days due to exceptionally large or small values of independent variables. Hence, the predicted values are likely to be quite different from the observed value for each observation. R-squared values of this study, however, are quite comparable to those of past studies that analyzed the variables of similar characteristics to the variables of this study: adult obesity study by Chou, et al. (2004) reported R-squared scores of

4.1% and 8.1%, and cigarette consumption study by Sloan and Trogdon (2004) reported R-squared scores ranged from 2% to 9%.

Another concern for the empirical models is multicollinearity between ACEs and the health behavioral variables since they are in the same empirical models. Studies (Anda, et al., 2006; Danese, et al., 2007; Corso, et al., 2008; Bellis, et al., 2017) reported that ACEs could become toxic stress and that the biological response to this toxic stress could be incredibly destructive and last a lifetime. Thus, a child who was exposed to ACEs was more likely to have learning and behavioral issues. It induced that individual ACEs would be significantly associated with health behavioral variables. However, this study finds that there is no significant correlation between those variables. All of the estimated correlation coefficients are less than 0.1 except current smoker: the correlation coefficients between current smoker and individual ACEs are from 0.099 to 0.153 (the results are not shown).

Physically unhealthy days: Regression results of physically unhealthy days are presented in Table 4. Participants who were married or employed were less likely to have physically unhealthy days than those who were not married or not employed. Males had more physically unhealthy days than females except for the age group 18-29. Participants who completed high school or higher level of education were less likely to have physically unhealthy days than those who did not complete high school. It suggests that higher-educated individuals are more efficient producers of health if other things held constant. Blacks had fewer physically unhealthy days per month than other races. In the results for health behavioral variables, participants who were underweight had 2.607 more physically unhealthy days per month than participants who were normal weight in the age group 60+. It is significantly greater than any other coefficient of the weight categories. Participants who were current smokers had more physically unhealthy days than participants who were currently non-smokers. Alcohol drinking was negatively associated with physically unhealthy days across all age groups except for the age group 18-29. As expected, physical exercise would significantly improve physical health across the age subgroups. Survey participants aged 50-59 who participated in physical activities were less likely to have physically unhealthy days by 4.495 per month than participants who did not currently participate in physical activities.

Table 4: Regression results of physically unhealthy days[a]

	Age 18-29	Age 30-39	Age 40-49	Age 50-59	Age 60+
Constant	4.487 (208.831)	5.301 (222.848)	11.655 (413.340)	13.993 (416.864)	8.544 (264.343)
Socio-Demographic Variables					
Married	-0.002 (-0.187)[b]	-0.113 (-11.904)	-0.116 (-11.060)	-0.180 (-14.721)	0.301 (26.686)
Employed	-0.972 (-117.511)	-2.099 (-200.503)	-4.961 (-399.014)	-5.582 (-446.734)	-2.485 (-212.713)
Male	-0.016 (-2.052)	0.358 (42.046)	0.151 (16.306)	0.144 (13.885)	0.528 (51.270)
Less HS	---	---	---	---	---
HS	-0.494 (-35.021)	-0.106 (-7.034)	-0.902 (-52.991)	1.600 (87.091)	-0.606 (-38.398)
Some college	-0.028 (-2.028)	0.188 (12.663)	-0.719 (-42.627)	1.917 (105.386)	-0.999 (-62.473)
Income25	---	---	---	---	---
Income2550	-0.675 (-69.793)	-1.060 (-90.501)	-2.317 (-158.896)	-2.915 (-182.659)	-2.299 (-176.604)
Income5075	-0.464 (-35.418)	-1.131 (-79.495)	-3.497 (-210.036)	-2.786 (-155.130)	-2.873 (-166.600)
Income75+	-0.915 (-79.459)	-1.527 (-110.437)	-3.730 (-229.150)	-2.789 (-155.402)	-2.400 (-135.048)
Other Races	---	---	---	---	---
White	-0.016 (-2.052)	0.594 (46.048)	0.751 (46.616)	-2.202 (-104.317)	0.563 (23.544)
Black	-1.069 (-72.586)	-0.847 (-53.916)	-1.375 (-70.314)	-3.602 (-139.541)	-0.726 (-25.058)
Health Behavioral Variables					
Normal weight	---	---	---	---	---
Underweight	-0.150 (-6.583)	-0.958 (-25.585)	0.785 (15.487)	0.394 (7.252)	2.607 (61.129)
Overweight	-0.123 (-13.685)	-0.138 (-14.226)	0.169 (14.819)	-0.347 (-26.342)	0.357 (29.118)
Obese	-0.017 (-1.678)[b]	0.918 (88.971)	1.012 (86.817)	0.750 (55.935)	1.304 (99.386)
Current smoker	0.771 (80.419)	0.275 (28.272)	0.569 (50.714)	1.096 (85.694)	0.552 (36.206)
Current drinker	0.063 (7.706)	-1.264 (-144.906)	-0.764 (-80.706)	-0.948 (-86.756)	-1.831 (-168.410)
Current Exercise	-1.219 (-109.464)	-1.787 (-166.281)	-2.289 (-202.876)	-4.495 (-369.609)	-3.757 (-338.674)
ACE Scores					
ACE0	---	---	---	---	---
ACE1	0.198 (19.149)	0.756 (70.942)	0.111 (9.573)	-0.035 (-2.660)	1.077 (89.310)
ACE2	0.820 (66.269)	1.607 (123.729)	1.132 (82.055)	1.102 (66.015)	0.069 (4.211)
ACE3	-0.173 (-12.289)	1.370 (93.207)	1.006 (63.724)	1.931 (101.718)	2.186 (105.348)
ACE4	0.628 (39.733)	1.726 (109.428)	1.468 (74.792)	1.851 (85.657)	1.525 (59.479)
ACE5+	1.561 (122.127)	1.956 (142.548)	2.566 (161.539)	3.578 (190.049)	4.454 (150.365)
R-Square	0.042	0.102	0.231	0.249	0.124

*Notes:*a. The t-statistics are in parentheses. All estimated coefficients are statistically significant at 95 percent level of confidence except bs. Regressions are weighted by the BRFSS sample weight factor. State and year coefficients are not shown. There are 3,602,019 observations in the regressions.

In the results for the ACE scores, all of the estimated coefficients for the age group 18-29 were relatively small compared with the coefficients for other age groups. The estimated coefficients of ACE5+ significantly increased from 1.561 in the age group 18-29 to 4.454 in the age group 60+. Especially, participants aged 60+ with ACE5+ had 4.454 more unhealthy days per month than participants aged 60+ who experienced none of the ACEs. It induces that the dosage effect of ACEs on physical health gets more severe as age rises. Overall, the negative effect of ACEs on physical health outcomes appeared at the age group 18-29 and persisted into the late stages of life. Put differently, the ACEs were significantly associated with negative physical health outcomes throughout the life course.

Mentally unhealthy days: The regression results of the mentally unhealthy days are presented in Table 5. In the results for socio-demographic variables, participants who were married, employed, or male were less likely to have mentally unhealthy days than their counterparts. Also, participants who completed high school or higher levels of education were less likely to have mentally unhealthy days than participants who did not complete high school. In the results for the income category, participants who reported an annual household income of $25,000 or more were significantly less likely to have mentally unhealthy days than participants who reported an annual household income of less than $25,000 across all age groups. In the results for health behavioral variables, obese participants were more likely to have mentally unhealthy days than participants with normal weight. Current smokers were

more likely to have mentally unhealthy days than non-smokers. Participants who participated in any physical activities were less likely to have mentally unhealthy days than participants who did not.

Table 5: Regression results of mentally unhealthy days

	Age 18-29	Age 30-39	Age 40-49	Age 50-59	Age 60+
Constant	5.968 (214.297)	5.573 (189.522)	8.962 (291.229)	8.880 (273.963)	3.799 (159.533)
Socio-Demographic Variables					
Married	-0.354 (-28.503)	-1.041 (-88.842)	-0.401 (-34.944)	-0.641 (-54.426)	-0.294 (-35.356)
Employed	-0.737 (-68.703)	-1.456 (-112.499)	-4.157 (-306.420)	-3.075 (-254.844)	-0.551 (-64.004)
Male	-1.192 (-187.004)	0.330 (31.343)	-0.623 (-61.769)	-0.794 (-79.037)	-0.413 (-54.453)
Less HS	---	---	---	---	---
HS	-0.530 (-28.957)	-0.056 (-3.000)	-0.379 (-20.406)	1.121 (63.169)	-0.184 (-15.876)
Some college	-1.216 (-66.943)	-0.210 (-11.456)	-0.302 (-16.389)	1.476 (84.038)	-0.158 (-13.433)
Income25	---	---	---	---	---
Income2550	-1.102 (-87.913)	-1.248 (-86.241)	-1.930 (-121.317)	-2.756 (-178.851)	-1.108 (-115.484)
Income5075	-1.234 (-72.659)	-1.297 (-73.731)	-2.889 (-159.024)	-2.835 (-163.487)	-1.396 (-109.858)
Income75+	-1.003 (-67.173)	-1.728 (-101.094)	-3.417 (-192.368)	-3.840 (-221.588)	-1.369 (-104.520)
Other Races	---	---	---	---	---
White	0.837 (59.275)	0.315 (19.754)	1.199 (68.183)	-1.276 (-62.596)	-0.499 (-28.364)
Black	-0.904 (-47.349)	0.076 (3.897)	-0.980 (-45.906)	-3.053 (-122.450)	-0.502 (-23.514)
Health Behavioral Variables					
Normal weight	---	---	---	---	---
Underweight	1.628 (55.128)	1.977 (42.709)	-0.676 (-12.219)	4.240 (80.817)	0.635 (20.189)
Overweight	-0.110 (-9.427)	-0.020 (-1.673)	0.363 (29.116)	-0.097 (-7.639)	0.208 (22.974)
Obese	0.815 (62.895)	0.884 (69.349)	0.912 (71.695)	0.938 (72.464)	0.900 (93.067)
Current smoker	1.217 (97.969)	1.589 (132.283)	1.463 (119.552)	1.654 (133.950)	1.548 (137.648)
Current drinker	0.318 (29.856)	-0.615 (-57.060)	0.173 (16.791)	0.147 (13.966)	-0.658 (-82.133)
Current Exercise	-1.744 (-120.817)	-1.538 (-115.778)	-1.962 (-159.381)	-2.254 (-191.980)	-0.821 (-100.485)
ACE Scores					
ACE0	---	---	---	---	---
ACE1	0.512 (38.147)	1.013 (76.914)	0.203 (16.065)	0.391 (30.816)	0.431 (48.434)
ACE2	1.847 (115.208)	2.008 (125.103)	0.752 (49.977)	1.655 (102.699)	1.018 (84.732)
ACE3	3.561 (194.832)	2.066 (113.737)	1.545 (89.641)	1.797 (98.016)	1.104 (72.212)
ACE4	3.454 (168.721)	2.066 (105.973)	2.474 (115.541)	3.257 (156.069)	2.552 (135.120)
ACE5+	5.289 (319.292)	4.505 (265.603)	3.645 (210.312)	5.667 (156.069)	5.026 (230.270)
R-Square	0.143	0.121	0.189	0.199	0.066

*Notes:*The t-statistics are in parentheses. All estimated coefficients are statistically significant at 95 percent level of confidence. Regressions are weighted by the BRFSS sample weight factor. State and year coefficients are not shown. There are 3,602,019 observations in the regressions.

Table 6: Regression results of unhealthy days for individual ACEs[a]

	Age 18-29	Age 30-39	Age 40-49	Age 50-59	Age 60+
Physically Unhealthy Days					
Physical abuse	-0.041 (-3.242)	0.508 (40.024)	0.793 (57.529)	0.443 (26.264)	0.543 (29.820)
Emotional abuse	1.184 (127.046)	0.428 (43.938)	0.438 (40.602)	1.017 (79.121)	0.257 (19.082)
Sexual abuse	1.630 (122.669)	1.325 (98.327)	0.899 (64.686)	1.443 (87.539)	1.220 (63.647)
Mental Illness	0.089 (8.561)	1.283 (116.616)	2.195 (168.933)	0.693 (45.293)	1.124 (60.819)
Substance abuse	-0.341 (-32.289)	-0.155 (-14.700)	0.192 (17.028)	0.565 (44.180)	-0.179 (-13.516)
Incarceration	-0.112 (-9.400)	-1.579 (-114.093)	0.304 (17.016)	1.493 (62.990)	2.263 (77.009)
Separation/divorce	-0.452 (-52.972)	0.490 (55.994)	-0.079 (-7.837)	0.447 (33.729)	0.606 (40.327)
Domestic violence	0.568 (46.143)	0.354 (29.142)	-0.614 (-45.226)	-0.256 (-16.359)	0.702 (40.185)
Mentally Unhealthy Days					
Physical abuse	0.571 (34.714)	-0.003 (-0.199)[b]	1.682 (112.723)	1.369 (84.383)	0.329 (24.498)
Emotional abuse	1.231 (101.920)	1.694 (140.624)	0.814 (69.734)	0.673 (54.535)	0.999 (100.843)
Sexual abuse	2.468 (143.285)	0.963 (57.780)	1.667 (110.730)	3.007 (189.809)	2.121 (150.276)
Mental Illness	2.336 (173.414)	2.343 (172.304)	3.145 (223.662)	1.999 (136.031)	0.395 (29.018)
Substance abuse	-0.080 (-5.838)	-0.098 (-7.532)	0.004 (0.349)[b]	0.261 (21.212)	0.292 (29.968)
Incarceration	0.475 (30.751)	0.424 (24.795)	-0.774 (-39.984)	1.124 (49.342)	0.916 (42.326)
Separation/divorce	0.387 (34.995)	0.136 (12.567)	-0.455 (-41.787)	0.312 (24.488)	0.408 (36.919)
Domestic violence	0.676 (42.327)	0.371 (24.697)	-0.735 (-49.997)	0.060 (3.998)	0.471 (36.599)

*Notes:*a. The t-statistics are in parentheses. All estimated coefficients are statistically significant at 95 percent level of confidence except bs. Regressions are weighted by the BRFSS sample weight factor. State and year coefficients are not shown. There are 3,602,019 observations in the regressions.

In the results for the ACE scores, participants aged 40-49 had the fewest mentally unhealthy days across all ACE score categories. The magnitude of the estimated coefficients of ACE scores for the mentally unhealthy days in the age group 18-29 was significantly greater than the magnitude of the coefficients for the physically unhealthy days in the same age group. Like the regression results for physically unhealthy days, the negative effects of the ACE scores on mental health appeared in an early stage of adult life and prolonged throughout the life course.

Individual ACEs results for both physically and mentally unhealthy days: Additionally, the author substitutes individual ACEs for ACE scores in the empirical models to test the effect of the individual ACEs on health outcomes (Table 6). Sexual abuse and mental illness had the greatest negative association with both physical and mental health. The estimated coefficient of incarceration for physically unhealthy days in the age group 60+ was significantly larger than all other coefficients in the same age group. For the same age group, participants who reported experiencing incarceration during their childhood had 2.263 more unhealthy days than participants who had no incarceration experience. The empirical results for the individual ACEs on both physical and mental health outcomes consistently showed that the adverse effects of individual ACEs on both physical and mental health outcomes persisted throughout an individual's life course.

DISCUSSION

The study (Son, 2016) found a significant association of the individual ACEs and ACE scores with physically and mentally unhealthy days in adulthood. The finding suggested that negative effects of ACEs on health outcomes may persist for several decades after their occurrence due to the respondents with an average age of 47.57 years in the study. However, the prolonged existence of the adverse effects of ACEs on health outcomes throughout the life-course was not justified because the study dealt with the adult population aged 18 or older. To reveal the persistence of the adverse effects throughout the lifespan, this study divides the adult population into five age groups. The study conducts a cross-sectional multiple regression using the 2012 BRFSS data. The number of unhealthy days, a measure of the HRQOL, is used as a dependent variable in the analytical models.

In the multiple regression results for physically unhealthy days, the estimated coefficients of all ACE scores for the age group 18-29 are relatively small compared with those for other age groups. It suggests that the effects of accumulative ACEs on physical health outcomes are relatively insignificant for young adults. The estimated coefficients of ACE scores drop and rebound at the age group 40-49 across all ACE scores (Figure 1). The estimated coefficient of ACE5+ increases significantly from 1.561 for the age group 18-29 to 4.454 for the age group 60+. It implies that participants who reported exposing ACE 5 or more are significantly vulnerable to adverse physical health outcomes in the late stage of life. This is especially true of participants who are in the age group 60+ with ACE5+ – they have 4.454 more physically unhealthy days than participants who did not have exposure to any ACE in the same age group. Overall, the negative effect of ACEs on physical health outcomes presents at an early stage of adulthood and persists into the late stage of life. It is assumed that the ACEs are significantly associated with negative physical health outcomes throughout the life course. In the multiple regression results for mentally unhealthy days, participants aged 40-49 have the least negative effect of cumulative ACE scores on mentally unhealthy days (Figure 2). Importantly, the negative effect of the ACE scores on mental health outcomes also appears in early adulthood. In addition, the magnitude of the estimated coefficients for the mentally unhealthy days for especially the age group 18-29 is significantly larger compared with the magnitude of the estimated coefficients for the physically unhealthy days (see Figure 1 and 2).

In summary, the estimated coefficients of all ACE scores for the mentally unhealthy days are greater than the coefficients for the physically unhealthy days in all age groups. The result suggests that the adverse effects of ACEs on mental health are more significant than the effects of ACEs on physical health. The negative physical health impacts of ACE5 constantly increase as the age group rises (Figure 1). Lastly, the empirical results indicate that the adverse impacts of cumulative ACE scores on both physical and mental health outcomes are onset at the early stage of adulthood and persist into the late stage of life. Noticeably, the adverse effects slightly drop and rebound at the middle age group, ages 40-49, (Figures 1 and 2), and the adverse associations of ACEs on HRQOL remain throughout the life course.

Figure 1: Estimated coefficients of physically unhealthy days

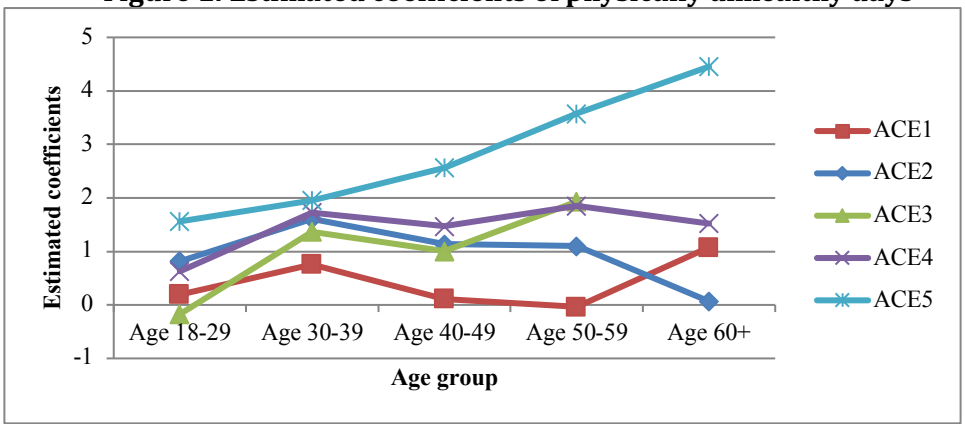
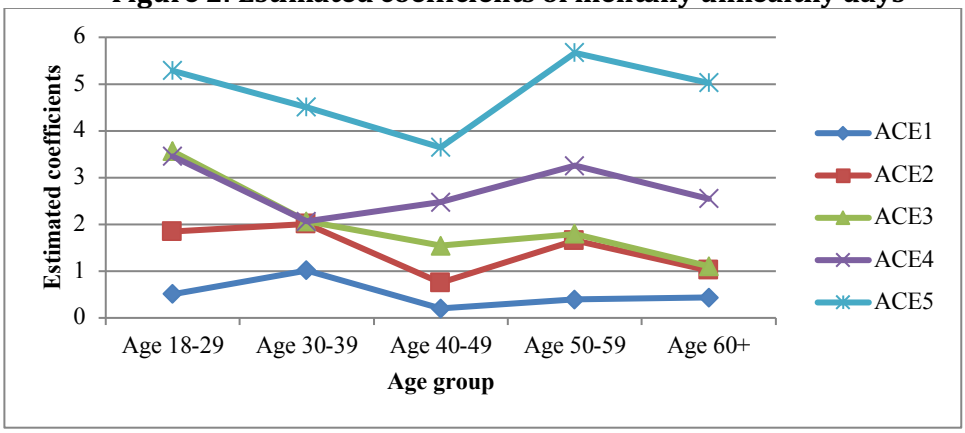


Figure 2: Estimated coefficients of mentally unhealthy days



There are some limitations to this study. First, using the measure of HRQOL from the BRFSS is the one that is well described in the previous studies (Son, 2016; Son 2018). Second, measuring ACEs from self-reported survey data, the BRFSS data does not provide the duration and timing of the adverse childhood experiences. A child who has longer exposure to ACEs might be more vulnerable to chronic health problems than a child who has acute exposure because the child who has longer exposure might have a more traumatic brain injury. Also, previous studies (Iniguez and Stankowski, 2016; Schalinski, et al., 2016; Bellis, et al., 2017) reported that the timing of ACEs was a strong indicator for health outcomes in adulthood. The studies sought to clarify the impact of timing of distinct ACEs on symptom severity experienced in adulthood, in support of stress-sensitive periods in brain development. Another study (Kaplow and Spatz Widom, 2007) found that early onset of child maltreatment predicted more symptoms of anxiety and depression in adulthood and that later onset of child maltreatment was predictive of more behavioral problems in adulthood. Third, only five states implemented the ACEs module in the 2012 BRFSS. The five states may not represent the entire states in the United States although the CDC conducted the stratified random sampling to select individual survey

participants. Finally, since the data in this study are a cross-sectional design for finding the effect of ACEs on HRQOL across age-groups, the limitations of the potential impact of cohort effects on the findings arise, and the data have lacks a developmental course to the ACEs impact.

The current study finds that the adverse effects of cumulative ACE scores on both physical and mental health outcomes are onset at the early stage of adulthood and remain throughout the life course. These remarkable findings could contribute to the existing literature on the effect of ACEs on HRQOL by providing additional insight into the adverse association of ACEs with HRQOL in adulthood. The ACEs are common but preventable. A child who has ACEs is more likely to have learning and behavioral issues, and these adverse effects can be magnified through generations if the traumatic experiences are not addressed. Reducing ACEs has the potential to a reduction in the prevalence of many health problems and employment problems, resulting in significant cost savings for private and public sectors (Anda and Brown, 2010).

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