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Adolescent Physical Activity and Education

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Adolescent Physical Activity and Education

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSPHY

in Education

by

Kenneth T.H. Lee

Dissertation Committee:
Distinguished Professor Greg Duncan, Chair
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2016

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ACKNOWLEDGMENTS

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In particular, I would like to express special thanks for my advisors, Greg Duncan and Deborah Lowe Vandell. My vocabulary lacks the proper words and phrases to express the gratitude that I have for the support, advice, mentorship, and prodding that I have received during my time at UC Irvine. One of my goals in my life is to provide someone the same support that I have received from my advisors.

I would also like to thank my family and friends for the support that they have provided me, despite having zero understanding of what I actually do. On behalf of my mental sanity and to detriment to my liver, there is no way that I would have finished this doctorate or this dissertation without the time spent away from conducting research.

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Vandell, D.L.; **Lee, K.T.H.**; Auger, A.; Pierce, K. (Revise and Resubmit) Cumulative and differential effects of early child care and organized afterschool activities on adolescent functioning

In Preparation

Lee, K.T.H. (In preparation) The impact of adolescent physical activity on educational attainment. *[Dissertation Chapter 1]*

Lee, K.T.H. (In preparation) The impact of adolescent physical education classes on educational attainment. *[Dissertation Chapter 2]*

Lee, K.T.H. (In preparation) Varsity sports participation and academic performance. *[Dissertation Chapter 3]*

Lee, K.T.H.; Duncan, G.J. (In preparation). Peer problems in middle childhood predict early adult obesity.

Bohnert, A.; Zarrett, N.; **Lee, K.T.H.**; Vandell, D.L. (In preparation) The effects of structured programming on summertime weight gain.

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Graduate Student Researcher on NIH-funded P01 Project Summer 2012—Summer 2016
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- Assess the extent to which augmenting skills, health, and behaviors at various points in childhood and adolescence are predictive of adult labor market and health outcomes.
- Analyze multiple large nationally representative longitudinal datasets
- Data Sets Used: National Longitudinal Survey of Youth 1979, National Longitudinal Survey of Youth 1979 Child and Young Adult Supplement, National Longitudinal Survey of Youth 1997, Integrated Fertility Survey Series (National Surveys of Family Growth), Natality Detail File Series (1968-2006), NICHD Study of Early Child Care and Youth Development, The National Longitudinal Study of Adolescent to Adult Health (Add Health)

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Undergraduate Research Assistant at the Institute for Applied Research in Youth Development **Spring 2010—Winter 2010**
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SAT/ACT Instructor **Summer 2011 – Summer 2015**
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- Teach SAT Mathematics and ACT Mathematics and Science in an out-of-school time setting to high school students
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INVITED LECTURES

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ABSTRACT OF THE DISSERTATION

Adolescent Physical Activity and Education

By

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Doctor of Philosophy in Education

University of California, Irvine, 2016

Distinguished Professor Greg J. Duncan, Chair

As the focus on academic performance has increased in recent years due to national and state policies such as the Every Student Succeeds Act, instructional time for subjects such as mathematics and language arts has increased at the expense of physical activity (PA) opportunities in schools such as physical education (PE) classes. A potential consequence of increased instruction time in these curricular subjects is a decrease in daily PA, which may adversely impact both youth health and education.

This dissertation is composed of three studies focused on the relationship between adolescent PA and educational outcomes using data from the National Longitudinal Study of Adolescent Health (Add Health), a nationally representative sample of adolescents surveyed four times starting in 1994 when they were between grades 7-12 until 2008 when they were between the ages of 24-32. The wealth of data provided in the Add Health study allows for the use of statistical methods such as instrumental variables and individual fixed effects that provide more informative estimates than typical correlational approaches. The first study uses an instrumental variables strategy to estimate the impact of adolescent PA on educational attainment, while the

second and third studies use instrumental variables and individual fixed effects adjustments, respectively, to evaluate potential school-based policy levers that can increase adolescent PA.

Results from the first study using instrumental variables demonstrate that a standard deviation increase in PA increases years of completed schooling by 1.54 years, and about a third of this relationship is mediated by improvements in cognition. Results from the second study using instrumental variables show an additional hour of weekly PE increases years of completed schooling by .30 years. The final study uses individual fixed effects to find varsity sports participation to be positively associated with increases in educational performance for certain academic subjects but these estimates vary by gender**.**

Reductions in PA may be detrimental to the academic success of adolescents. Results from this dissertation suggest increases in PA can improve the academic success of youth, which could be an additional benefit above and beyond the health benefits of PA.

INTRODUCTION

During the past two decades, national and state policies to improve educational performance and attainment have focused primarily on factors affecting classroom instruction, such as mandating the use of standardized assessments (No Child Left Behind) and curricular reforms (Common Core State Standards Initiative, Every Student Succeeds Act). As the focus on academic performance has increased, time allotted to physical activity opportunities in schools via recess and physical education have been reduced to promote more instruction time for subjects such as mathematics and language arts that are tested in these standardized assessments (Centers for Disease Control and Prevention, 2010; Institute of Medicine, 2013). As most US adolescents spend the majority of their waking hours in schools, a potential consequence of increased instruction time in these curricular subjects is a decrease in daily physical activity. This decrease in physical activity may have adverse impacts not only on youth health but also on educational performance and attainment.

This dissertation is composed of three studies centered around the relationship between physical activity and educational performance and attainment. The first study explores the impact of adolescent physical activity on educational attainment using quasi-experimental methods. Prior studies have often focused on educational performance, but not attainment, as an outcome of physical activity. Prior studies have also used samples of children, rather than adolescents. The second and third chapters examine potential educational policy levers that can increase physical activity in adolescents: physical education classes and school-based varsity sports. Prior research has not been able to identify a causal relationship of adolescent physical education on educational attainment, and the extant research estimating the relationship between varsity sports participation on educational performance fails to account for unobservable factors that can bias the relationship.

Physical Activity and Education

Various reviews of observational and experimental studies show positive or null associations between physical activity and academic performance with little to no published evidence of negative relationships (Centers for Disease Control and Prevention, 2010; Fedewa & Ahn, 2011; Hattie & Clinton, 2012; Howie & Pate, 2012; Strong et al., 2005; Trudeau & Shephard, 2008). Physical activity has also been linked to benefits in cognition and behaviors that may in turn improve academic performance (Strong et al., 2005; Tomporowski, 2003). For example, playing sports not only requires physical ability but also requires the mental capacity and ability to make important decisions. Among others, team sports like football or basketball require learning systems of offense and defense and the ability to coordinate one's actions with those of teammate. Increased participation in these sports of activities can provide increased opportunities to make these decisions, which may increase cognition.

Additionally, engagement in physical activity can be considered a cognitive activity that recruits higher-order brain regions and requires adaptive thinking (Best, 2010; Hillman, Erickson, & Kramer, 2008). Regular exercise has been found to produce changes in brain functions that underlie cognition and behavior (Colcombe et al., 2004a; Dishman et al., 2006). Neuroimaging studies of physical activities have also revealed differences in cognitive function that are related to physical activity behavior in adults (Hillman et al., 2008; Kramer & Erickson, 2007). Among others, increases in aerobic exercise has been linked to increases in cerebral blood volume (Pereira et al., 2007) as well as increases in gray matter volume in the frontal and temporal cortex (Colcombe et al., 2006).

Even though the majority of papers show a positive or, at worst, null effect of physical activity on constructs related to short-term educational outcomes such as academic performance in children, there is a void in the literature examining the impact of physical activity on long-term educational outcomes such as years of completed schooling, high school graduating rates, college attendance, or college graduation. Because extant research on physical activity and education has focused around observational studies, small experiments, or neuroimaging studies in adults, there are no studies that have examined a causal link between physical activity and education using a longitudinal data set of a nationally representative sample of adolescents.

Physical Education and Education

Schools are an important setting in providing opportunities for young people to engage in physical activity (Bailey, 2006; Centers for Disease Control and Prevention, 2010; Wechsler, Devereaux, Davis, & Collins, 2000). In particular, state and district policy changes in physical education (PE) class requirements are a potentially promising and relevant policy lever to increase adolescent physical activity. PE classes often represent the sole source of physical activity within the guidelines and framework of a state's curricular mandates for schools.

Participation in PE however, is widely inconsistent across the US. In 2013, the prevalence of ever having attending PE classes ranged from 31% to 93% across 37 states[1]; across 19 large urban school districts, the prevalence ranged from 28% to 85%[2]. Students also appear to participate less in PE as they age—the prevalence of attending PE classes was higher amongst

[1] Excluded states include California, Colorado, Connecticut, Indiana, Iowa, Minnesota, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, and Washington

[2] Large urban school districts include: Baltimore, MD; Boston, MA; Broward County, FL; Charlotte-Mecklenburg, NC; Chicago, IL; Detroit, MI; District of Columbia; Duval County, FL; Houston, TX; Los Angeles, CA; Memphis, TN; Miami-Dade County, FL; Milwaukee, WI; New York City, NY; Orange County, FL; Palm Beach County, FL; Philadelphia, PA; San Bernardino, CA; San Diego, CA; San Francisco, CA; Seattle, WA.

9th-grade students(64%) than 10th-grade (51%), 11th-grade (40%), and 12th-grade (35%) students (Kann et al., 2014).

Across the U.S., PE participation has also decreased over the past decade. The percentage of high school students who attended PE classes daily decreased from 42% in 1991 to 25% in 1995 and has remained at roughly that level until 2013 (29%). In 2013, 42% of 9th-grade students, but only 20% of 12th-grade students, attended PE class daily (Kann et al., 2014). These percentages do not come close to the guidelines regarding daily physical activity provided by the US Health and Human Services Department, which recommends one or more hours of physical activity each day (Institute of Medicine, 2013).

The extant literature on the returns of PE is sparse. Some of the best work on the returns of PE are focused around its health benefits in children, such as increasing the intensity of vigorous exercise, engaging in strength-building activity, or decreasing the probability of obesity (Cawley, Frisvold, & Meyerhoefer, 2013; Cawley, Meyerhoefer, & Newhouse, 2007). However, educational attainment is not considered an outcome of interest in these studies, especially for adolescents.

In a review of literature examining the influence of sports, PE, or physical activity on academic performance, Trudeau and Shephard (2008) identified only seven studies focusing on PE programs that use experimental methods to make causal inferences. The authors found that that intervention programs that increased weekly PE time reduced time allocated for other curricular subjects. At the same time, they found either no change or a slight improvement in child academic outcomes and the authors suggested that the efficiency of learning was enhanced. Although they found the impacts of these programs to be null or positive, the samples for each of the studies are limited to children, small in size, and not nationally representative. Further research is needed to understand the returns to educational attainment of additional time in adolescent physical education.

School-Based Sports and Education

Another potentially relevant policy lever to increase physical activity in schools may be through increasing participation in school sports programs, such as football, soccer, basketball, and baseball/softball teams, among others. The number of sports teams offered in schools varies significantly across schools and additional funding to increase a school's sports offerings can increase participation and subsequently, the amount of adolescent physical activity. These sports programs often occur outside of the normal school curricular hours but are organized by the school and require students to perform to an academic standard as a prerequisite for participation. Participating in these school-based extracurricular sports programs has previously been considered a type of school-based physical activity (Trudeau & Shephard, 2008). In some districts and schools, participation in a school-based sports team can be used as a substitute for a PE class requirement.

Unlike the literature on physical activity and PE in children, sports participation has generally been positively linked to numerous educational outcomes in a number of comprehensive reviews (Farb & Matjasko, 2012; Feldman & Matjasko, 2005; Trudeau & Shephard, 2008). Although the research on the associations between sports and education has been promising, the studies in these reviews relied primarily on correlational analyses, and the estimates can be biased by the inability to account for unobservable factors. By far, the largest issue lies with unobservable factors that account for selection into sports participation (Farb & Matjasko, 2012).

One of the more promising studies to account for some of the unobservable factors that can bias the relationship between sports participation and education used an individual fixed effects strategy to test whether sports participation provides an immediate return to student learning (Lipscomb, 2007). This method compares the same individual at different time points and exploits changes in an individual's participation in sports to assess the association between sports participation and test scores in math and science while controlling for time-invariant individual characteristics such as gender and race. Lipscomb found participation in sports to be associated with a two percent increase in math and science scores. However, it is unclear if the results pertain to school based sports programs or to extramural sports programs that do not require the same set of academic standards that are typically required in varsity sports programs.

Current Study

This dissertation focuses on three promising areas for which the research literature lacks definitive studies for adolescents: physical activity, physical education in schools and school-based varsity sports participation. This dissertation is composed of two studies focused on estimating the causal impact of physical activity on educational attainment using quasi-experimental methods and a third study focused on the relationship between varsity sports participation and educational performance using individual fixed effects adjustments that control for unobservable time-invariant individual factors. The first chapter will focus on the impact of physical activity on education while the second chapter seeks to understand the role of PE participation on education. The last chapter will focus on the educational benefits of school-based extracurricular sports activities.

DATA

Each chapter of this dissertation uses restricted data from the National Longitudinal Study of Adolescent Health (Add Health), a prospective longitudinal study of a nationally representative sample of adolescents who were in grades 7 through 12 in the U.S., which began during the 1994-1995 school year. The Add Health dataset consists of multiple waves of data, including in-home surveys of adolescents and their parents, in-school surveys of adolescents who were administered the in-home surveys and their peers, and contextual information of the adolescent's school from a survey completed by school administrators. Adolescents who were administered the in-home survey were considered the "core" sample and were followed until the ages of 24-32 through a series of in-home interviews conducted in 1994-1995, 1996, 2001-02, and 2007-08.

"Core" sample participants reported on their social, economic, psychological, and physical well-being as well as contextual data on family, neighborhood, community, and school relationships on the in-home survey. In addition, existing databases with information about respondents' neighborhoods and communities (e.g. Census of Population and Housing, 1990: Summary Tape File 3A, 1995 Uniform Crime Reporting, 1994 School Health Policies and Programs Study, etc.) were been merged with Add Health data, providing variables on geographic and household characteristics, income and poverty, and social programs and policies. Furthermore, in-school questionnaires of all the adolescents in the school and of the school administrator provide contextual information of the schools attended by the adolescents.

During Wave I of the data collection (1994-1995), 20,745 adolescents between grades 7-12 and 17,670 parents were interviewed through an in-home administration. 90,118 students and 144 school administrators were also surveyed through an in-school administration to obtain school characteristics of the adolescents in the “core” sample. In Wave III (2001-2002), 15,197 young adults originally in the study were interviewed again through an in-home administration when they were between the age of 18-26, and in Wave IV (2007-2008), 15,701 of the survey participants between the age of 24-32 were interviewed through an in-home administration. Add Health also includes measures of academic performance and experiences by collecting transcripts released by Wave III Add Health sample members (Figure 1).

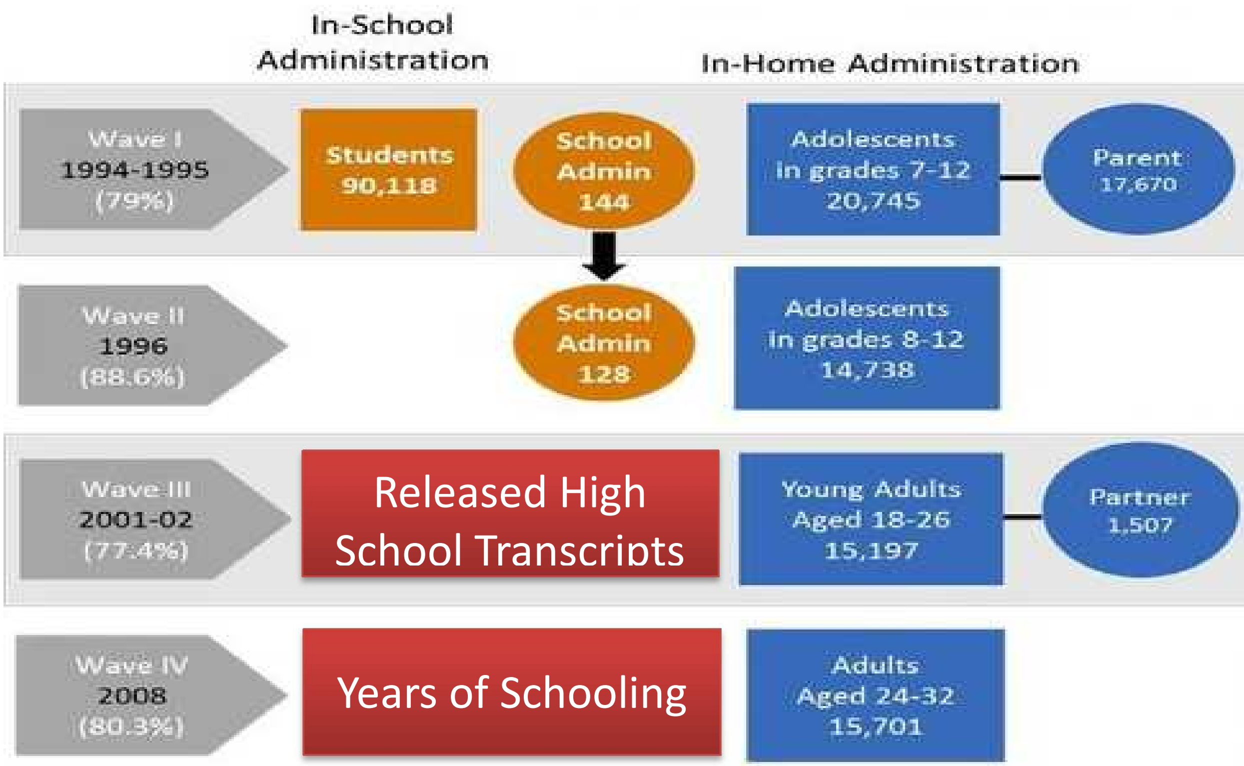
This dissertation takes advantage of physical activity measures in Wave I, such as amount of physical activity and intensity of participation in PE, to predict educational attainment reported in Wave IV. However, a typical OLS model could potentially be biased by a number of unobservable factors, such as selection into physical activity, and it would not be possible to make causal implications. These unobservable factors are included in the error term of an OLS model and may cause a biasing correlation between the physical activity variables and the error term.

To account for these unobservable factors, the first two studies of my dissertation will use instrumental variables, which is a method of estimation that is widely used in many economic applications when a correlation between the explanatory variables and error term is suspected. This method replaces the actual realized values of physical activity with predicted values of physical activity. Using this predicted value, I can obtain a consistent and causal estimate of the relationship between my measures of physical activity and educational attainment.

Predicted values of physical activity are formed by projecting the actual realized values of physical activity on a set of instrumental variables that are 1) related to the actual value of physical activity but 2) are uncorrelated with the error term. The studies in this dissertation will use additional databases merged onto the “core” sample, such as the 1990 Census of Population and Housing and the in-school questionnaires of students and school administrators, which provide contextual information about the adolescent's environment. This contextual information provides variation that is beyond the adolescent's control and are used as instrumental variables, which accounts for issues such as selection and measurement error. These instrumental variables will be used in a two-stage least squares model to produce causal estimates between my measures of physical activity and educational outcomes.

My third study will use individual fixed effects as another means to account for unobservable factors that can bias the relationship between varsity sports participation and educational performance. This method uses multiple observations of a given individual at differing points in time and compares the individual to him- or herself across these time points, controlling for time-invariant individual characteristics such as gender and race. The important source of identification comes from adolescents who participate in varsity sports in a given year. This method presents a very conservative estimate of the relationship between varsity sports participation and educational performance.

Figure 1
National Longitudinal Study of Adolescent Health (Add Health) Study Design



CHAPTER 1:

Impact of Adolescent Physical Activity on Educational Attainment

As the focus on academic achievement has increased, physical activity opportunities in schools have decreased in the United States. In particular, there have been pushes to reducing recess and physical education in schools to promote more instruction time and it not yet known how this decrease can have an impact on long-term educational outcomes such as years of completed schooling (Centers for Disease Control and Prevention, 2010). The majority of the extant literature focuses on the short term educational impacts of physical activity for children and it is important to see if the inferences from prior research are applicable for long term educational outcomes and for adolescents. Using a longitudinal dataset of a nationally representative sample of adolescents, this study estimates the magnitude of a causal link between adolescent physical activity and educational attainment in adulthood using instrumental variables. Additionally, the extent which this relationship is mediated by health, social-emotional development, and cognition are explored.

Impact of Physical Activity on Academic Achievement

Various reviews have summarized the link between physical activity and academic achievement. Tomporowski, Davis, Miller, and Naglieri (2008) show that there is evidence for a relationship between physical activity and academic achievement amongst youth in a review of five prospective and experimental studies that assessed the effects of chronic exercise on academic achievement as well as four correlational studies that assessed the relation between physical fitness and academic achievement. Their review found the results from the previous literature to be inconsistent. Of the five experimental studies that were published between 1967 and 2006, only one showed an improvement in academic achievement while the remaining four reported either inconclusive or null effects. However, three of the four correlational studies published between 2000 and 2007 found a positive association between physical fitness and children's academic achievement. Potential explanations for this lack of agreement may be due to tests that are not sufficiently sensitive to the effects of physical activity, different types of physical activity having differential impacts on academic outcomes, and differences in samples of children such as population characteristics or age. Regardless of these concerns, they conclude that time spent in physical education does not have a negative impact on children's academic progress.

In line with Tomporowski et al. (2008), a meta-analysis consisting of 59 studies spanning the years from 1947 to 2009 found a standard deviation increase physical activity to be associated with a .28 standard deviation increase in academic performance. Amongst the experimental and quasi-experimental studies in the meta-analysis, the authors found a standard deviation increase in physical activity increases academic performance by .35 standard deviations (Fedewa & Ahn, 2011). The authors also found that the positive effects from physical activity also apply to adolescents, although the majority of the studies in the meta-analysis used samples of children.

Taken together, these reviews hinted at a positive link between physical activity and academic performance. However, these reviews are focused on short-term outcomes such as test scores on a reading and mathematics assessment following an intervention. Potential long-term outcomes such as educational attainment are not considered. In addition, the prior correlational and longitudinal studies were unable to make causal claims and the experimental studies suffered from small sample sizes.

Impact of Physical Activity on Academic Performance and Cognition

Prior meta-analytic reviews also examine the links between physical activity and both academic achievement and cognition. For example, Sibley and Etnier (2003) conduct a meta-analysis and find a positive association between physical activity and academic performance, including grades, math assessments, and academic readiness, as well as cognitive assessments, including perceptual skills, intelligence quotient (IQ), in school-age children (age 4–18 years). However, only 16 of the 44 studies included in this review used a true-experimental randomized design and only nine of these 16 were published studies. The effect sizes from these 16 experimental studies ranged from zero to 1.49 with an average of .32 standard deviations.

In a separate literature review of 125 published observational or experimental studies, Howie and Pate (2012) found 12 experimental studies that examined the effect of physical activity on academic performance and 14 experimental studies that examined the effect of physical activity on cognition published after 2007. The majority of these published articles reported positive impacts of physical activity on academic performance and cognition but the sizes of the impacts were inconsistent across the studies. More importantly, little to no published evidence suggested a negative relationship between physical activity and educational outcomes.

The associations between increased physical activity and both academic performance and cognition had been found to be highly inconsistent across the studies in the reviews, perhaps due to differential amounts of physical activity, outcomes, and samples. The majority of these studies were also primarily focused on children 12 years old or younger—making it difficult to infer the potential educational benefits of physical activity for adolescents. The experimental studies in these reviews that make causal claims suffer from small sample sizes, which make it to infer the same effects across a larger population. These studies also fail to examine any long-term effects of physical activity, such as years of completed schooling.

Physical Activity in the Classroom

Another potential avenue to evaluate the impact of physical activity on educational outcomes is to evaluate school programs intended to improve health. One such program is TAKE 10!®, which was designed by elementary school teachers to reduce sedentary behavior during the school day and to increase structured minutes of physical activity in the classroom without sacrificing time dedicated to academic learning. At its core, TAKE 10!® combines academic instruction with 10 minute physical activity breaks. Kibbe and colleagues (2011), in reviewing the impact of this program, found that teachers are willing and able to implement classroom-based physical activity. They also found that this program improved reading, math, spelling, and overall academic performance. However, the outcomes assessed using the TAKE 10!® program are proximal to the time of the intervention, such as standardized test scores at the end of the year, and the long term outcomes such as years of completed schooling are not considered.

In a modified TAKE 10!® intervention called Physical Activity Across the Curriculum (PAAC), Donnelly and Lambourne (2011) used a 3-year cluster-randomized, controlled design and find a positive link between physical activity and educational performance. The 77 students who were in schools that incorporated increased physical activity in the classroom were compared against 90 students in control schools without additional physical activity each spring of the 3-year intervention. Similarly to the impacts of TAKE 10!® programs, the authors found physically active academic lessons to improve performance on a standardized test of reading, math, spelling, and overall academic performance. Similar to other studies in this field, the authors did not evaluate any long term outcomes such as educational attainment.

Classroom-based physical activity interventions, such as TAKE 10!® and PAAC, are focused on elementary school students and their effectiveness for adolescents is questionable.

For example, unlike elementary school teachers, it may be difficult for high school teachers to implement physical activity in their classrooms. Adolescents may balk at participating in classroom-based physical activity due to peer pressure and societal norms, making classroom-based physical activity an ineffective way to improve academic performance. High school administrators attempting to use classroom-based physical activity as a replacement for physical education may find it difficult to implement as high school students have varying schedules and classes. Most importantly, the extent to which classroom-based physical activity has an impact on long term educational outcomes, such as years of completed schooling, is yet to be determined.

Potential Mediating Mechanisms

In addition to examining the relations between physical activity and academic performance, many studies have explored the associations between physical activity and factors that can have a potential impact on educational attainment, such as improved health, "noncognitive" or socio-emotional behaviors, and cognition. These outcomes can potentially function as mediators in the relationship between physical activity and educational attainment.

Health.

One of the most established benefits of physical activity is improved health (Centers for Disease Control and Prevention, 2010; Currie, Stabile, Manivong, & Roos, 2010; Warburton, Nicol, & Bredin, 2006). Improvements in health can influence educational attainment by reducing school absenteeism. Prior research has found a relationship between absenteeism and academic performance (Shiu, 2001). Students who miss school fall behind their peers, are constantly trying to "catch up" on missed work, and most importantly, miss out on learning the skills and behaviors required for later educational attainment.

Behaviors.

Increases in physical activity can also have an impact on the development of so-called "noncognitive" behaviors (Netz, Wu, Becker, & Tenenbaum, 2005; Trudeau & Shephard, 2008; Van Der Horst, Paw, Twisk, & Van Mechelen, 2007). Decreases in behaviors such as anxiety, depression, school satisfaction and school connectedness as a function of increased physical activity can potentially improve adolescent academic performance. Recent research has shown the importance of these "noncognitive" behaviors on educational attainment (Heckman & Rubinstein, 2001; Lleras, 2008; Magnuson, Duncan, Lee, & Metzger, 2016).

Cognition.

A significant amount of neuroscience research has underscored the importance of physical activity on cognition, which is often shown to be predictive of academic performance in youth. In particular, engagement in physical activity can be considered a cognitive activity that recruits higher-order brain regions and requires adaptive thinking (Best, 2010; Hillman et al., 2008). Research using animal models showed that aerobic training increases cortical capillary blood supplies, the number of synaptic connections, and the development of new neurons—resulting in a brain that is more efficient, plastic, and adaptive (Colcombe et al., 2004a). In humans, regular exercise resulted in changes in brain functions that underlie cognition and behavior, such as greater task-related activity in the prefrontal and parietal cortices and increased activation of the anterior cingulate cortex (Colcombe et al., 2004a; Dishman et al., 2006).

The relationship between physical activity and cognition has primarily been explored in the aging literature, particularly with the reduction of neurodegenerative disorders such as Alzheimer's disease. Observational and randomized human clinical interventions suggest physical activity enhances cognitive ability and brain function, which protects against the development of neurodegenerative diseases (Buchman et al., 2012; Hillman et al., 2008; Kramer & Erickson, 2007). Neuroimaging studies of physical activities in humans have also revealed differences in cognitive function that are related to physical activity behavior (Hillman et al., 2008; Kramer & Erickson, 2007). Among others, increases in aerobic exercise was correlated with increases in cerebral blood volume (Pereira et al., 2007) as well as increases in gray matter volume in the frontal and temporal cortex (Colcombe et al., 2006).

Although neuroscience research has found some significant links between physical activity and cognition based around brain activity, the majority of the extant research has been focused on animals or on older humans. The extent to which physical activity has an impact on adolescents may be greater than reported in the literature as adolescents experience significant brain development during puberty (Dahl, 2004; Giedd et al., 1999). It may be possible that increases in physical activity during puberty may result in increased development in the brain. However, improvements in cognition may not prove to be significant in the context of education unless they are also associated with increases in measureable educational outcomes such as attainment.

Current Study

The extent to which physical activity is linked to education for adolescents is often neglected or not considered as important or urgent relative to other curricular subjects. This is most likely due to national and state education policies primarily focusing on factors affecting classroom instruction such as mandating the use of standardized assessments (No Child Left Behind) and curricular reforms (Common Core State Standards Initiative). The majority of papers regarding physical activity and academic performance in children showed a positive effect of physical activity on constructs related to academic performance, but the prior research primarily focused on children, not on adolescents. Furthermore, prior research neglected the impacts of physical activity on any long-term educational outcomes, such as years of completed schooling, high school graduating rates, college attendance, or college graduation. This study specifically addresses this void by examining the causal impact of physical activity on educational attainment for adolescents.

This study uses a longitudinal dataset of a nationally representative sample of adolescents to estimate the magnitude of a causal link between adolescent physical activity and educational attainment in adulthood. The quality and wealth of information in the data provides the means to use quasi-experimental methods to estimate the impact of additional physical activity on years of completed schooling. This paper also attempts to explain this link using mediators associated with health, social-emotional development, and cognition.

Data

The data are drawn from the National Longitudinal Study of Adolescent Health (Add Health), a prospective longitudinal study of a nationally representative sample of adolescents in grades 7 through 12 in the US during the 1994-1995 school year who were followed until 2007-2008. The Add Health dataset contains multiple surveys from different individuals, including in-home surveys of adolescents and their parents, in-school surveys of adolescents administered the in-home surveys and their peers, and contextual information of the adolescent's residence, including but not limited to, physical activity resources, climate, crime, and socioeconomic status.

Adolescents were interviewed four times with a series of in-home interviews conducted in 1994-1995 (Wave I), 1996 (Wave II), 2001-02 (Wave III), and 2007-08 (Wave IV) when they were between ages 24-32. The students who attended the same schools as those in the in-home interview (more than 90,000 adolescents) between grades 7 through 12 were also administered an in-school questionnaire in a 45- to 60-minute class period between September 1994 and April 1995 in Wave I.

This study draws data regarding physical activity from the Wave I in-home survey to predict educational attainment from Wave IV. Covariates from the in-home and in-school questionnaire from Wave I as well as contextual information regarding the adolescent's neighborhood and county provided in the Add Health acquired by merging information from additional datasets (e.g., 1990 Census of Population and Housing) to the core sample will be used to reduce bias in the relationship between physical activity and educational attainment. Mediators from the in-home questionnaire in Wave I will also be used to explain the processes or mechanisms in which physical activity is related to educational attainment.

This study consists of a sample of 17,457 adolescents who reported a non-missing value of the intensity of their physical activity during the Wave I in-home interview and their educational attainment when they were between ages 24-32 in Wave IV.

The Add Health study design uses a clustered sample in which the clusters are sampled with unequal probability—making the observations no longer independent and identically distributed. Failure to account for this type of study design usually leads to underestimating standard errors and false-positive statistical test results. To account for the potential bias that the study design may have on the analysis, the Add Health provides principal sampling unit identifiers to obtain unbiased estimates. Following the recommended guidelines for using the Add Health dataset, analysis include standard errors that are clustered by the principal sampling unit—a school identifier based on the school attended by the adolescents in Wave I.

Additionally, the contextual information provided in the Add Health, such as neighborhood physical activity resources, climate, county crime, and neighborhood socioeconomic status, can be used to make causal inferences between physical activity and educational attainment. These contextual factors are taken from numerous sources, such as the US Census and local climate stations. These factors can predict an unbiased estimate of physical activity, which can then be used to estimate educational outcomes. Table 1.1 provides the full sample descriptive information for the main predictor variable and outcomes of interest as well as descriptive information for the contextual variables that are used to estimate an unbiased and causal estimate for the relationship between physical activity and education outcomes as well as for the potential mediating variables. Table 1.2 provides descriptive information for the full sample for the covariates and Table 1.3 provides a correlation matrix between the main predictors and outcome variables.

Analytic Strategy

To estimate the relationship between physical activity on educational attainment, the estimated ordinary least squares (OLS) model typically used is:

$$Outcome_i = \beta_0 + \beta_1(Physical\ Activity)_i + \delta' X_i + \varepsilon_i \quad (1)$$

where $Outcome_i$ reflects the educational attainment outcomes for adolescent i. Physical $Activity_i$ corresponds to the number of times per week of participation in physical activity for adolescent i, and X_i captures the vector of demographic, family, and individual characteristics covariates. ε_i is the error term.

However, it would be unrealistic to expect that a typical OLS regression of educational attainment on physical activity would produce a consistent estimate of the impact of physical activity on these educational outcomes. The biggest potential issue is with “selection”—

adolescents who are healthier and enjoy physical activity are more likely to choose to participate in physical activity. This type of selection bias may generate a correlation between physical activity and educational attainment even if physical activity does not have a causal impact on educational attainment.

Another potential issue with a typical OLS model would be an adolescent's misreporting of physical activity. If physical activity is reported with error, the effect of physical activity on educational attainment would be understated as this misreport may also generate a correlation between physical activity and the outcomes of interest.

To account for the presence of these selection and misreporting issues, instrumental variables (IV) are used in a two-stage-least squares (2SLS) model to generate a consistent estimate of the impact of additional physical activity on educational attainment. The IV method addresses these problems by predicting variation in physical activity using measurable factors beyond the adolescent's control. The use of IVs also eliminates the influence of any measurement error in student reports of physical activity and can be used to obtain an unbiased predictor for physical activity, which can be used to estimate the causal impact of physical activity on educational attainment.

One potential instrument that can impact and consequently predict adolescent physical activity is the number of physical activity resources around an adolescent's residence. The availability of a greater number of physical activity resources allows more opportunities for a given adolescent to partake in physical activity. For example, adolescents who want to play a game of basketball would find it difficult to play if the neighborhood that they reside in lacks a basketball court—either at a local recreation center, a local park, or a school, among others. If an adolescent goes to the local recreation center to play basketball and finds it occupied, he or she may be able to still play basketball if there is a nearby park or school with a basketball court. If the number of physical activity resources is limited, the potential for adolescents to partake in physical activity may be hampered. The number of physical activity resources can have an impact on physical activity but should not have a strong correlation with a student's educational attainment as the intent behind the creation of these resources was to increase physical activity and not improve schooling outcomes. For example, a neighborhood park in a neighborhood is often constructed with the means of providing nearby residents a location to participate in physical activity and not intended to improve schooling outcomes for the neighborhood children.

It is important to note that the number of physical activity resources may not prove to be a good instrument by itself, as there may be additional factors that can impact the availability of these resources that are correlated to physical activity participation and educational attainment. For instance, the availability of these resources may be an indicator for the overall wealth of a given neighborhood. Wealthier neighborhoods often choose to invest more in physical activity resources for youth and neighborhood socioeconomic characteristics have been found to be a predictor for physical activity (Estabrooks, Lee, & Gyurcsik, 2003; Powell, Slater, Chaloupka, & Harper, 2006). To account for these socioeconomic characteristics that can bias the links between physical activity and educational attainment, I will condition on the median household income of an adolescent's census block group in the first stage of the 2SLS model, which ought to provide a good estimate of a neighborhood's socioeconomic status.

In addition to conditioning on block group median household income, another important factor to condition for is crime, which has been found to be a potential barrier to participation in physical activity (Gomez, Johnson, Selva, & Sallis, 2004; Gordon-Larsen, McMurray, & Popkin, 2000). To account for crime, the total crime rate of the adolescent's home county will be added as a covariate in the first stage of the 2SLS model. If the neighborhood that the adolescent lives in were riddled with crime, it would be dangerous for that adolescent to partake in physical activity outside of his or her home. High levels of crime would dissuade participation in physical activity, regardless of the number of physical activity resources around an adolescent's home.

Another important factor to consider is the fact that parents often choose to live in certain neighborhoods and it would be unrealistic to expect that the neighborhood in which an adolescent is raised is completely random. For example, many parents choose to live in certain neighborhoods that have high quality school systems or schools where school funding and resources are not an issue. These same schools are equipped with outdoor physical activity resources (e.g., track fields, outdoor basketball courts) that are open to the public outside of school operating hours and thereby provide adolescents with the opportunity to participate in physical activity. To account for parents choosing to live in certain neighborhoods due to the neighborhood schools, the amount per capita that a local government (i.e., county or district) spends on education will be used to control for some of these kinds of neighborhood selection factors.

Climate has also been found to significantly influence physical activity in the United States (Merrill, Shields, White, & Druce, 2005). For example, it may be less likely for an adolescent to partake in physical activity if he or she lived in a region that experienced significant rainfall, perhaps due to discomfort or inaccessibility. Among others, it would be difficult to play sports in an outdoor setting if it were raining. Climate must be conditioned upon in the first stage of the 2SLS model estimates and the amount of annual rainfall may present the best proxy for climate.

The estimated analytic model for this study requires a two-stage least squares (2SLS) model. The first equation runs an OLS regression of physical activity on the instruments to get a predicted value for physical activity:

$$\widehat{Physical\,Activity}_i = \gamma_0 + \gamma_1 Z_1 + \vartheta' Y_i + v_i \tag{2}$$

Where $\widehat{Physical\,Activity}_i$ is the predicted value for number of times per week for adolescent i, and Z_1 is the number of physical activity resources around the adolescent's home that will be used as the instrumental variable. Y_i captures the vector of aforementioned conditions in the first stage—block group median household income, county crime, local government direct expenditure per capita on education, and annual rainfall which will improve the instrumental variable specification. v_i is the error term. By forming predictions for physical activity to be used in the second stage, the correlation between the error term and independent variables can be corrected for. The fitted value of $\widehat{Physical\,Activity}_i$ would then be inserted into the original OLS equation from Equation 1:

$$Outcome_i = \beta_0 + \beta_1 \widehat{Physical\,Activity}_i + \delta' X_i + \epsilon_i \tag{3}$$

ϵ_i is a composite error term that is assumed to be uncorrelated with the predicted value of physical activity and X_i is the vector of demographic, individual, and family control covariates in the OLS model in equation 1. Provided its assumptions are met, this 2SLS model estimates the causal impact of physical activity on years of completed schooling as well as discrete educational attainment outcomes, such as graduating high school, attending college, and graduating from college.

In addition to estimating the causal impact of physical activity on educational attainment, the wealth of information in Add Health allows for the examination of mediators, that is, mechanisms through which physical activity can impact educational attainment. To test for mediation, a mediator variable is added to equation (3). Following the work of Baron and Kenny (1986), three separate criteria must be met in order for a factor to be considered a mediator. One of the criterions is for the original relationship between physical activity and the outcome (β_1 in Equation 3) to be reduced with the inclusion of mediators in the equation. This equation would simply be an extension of Equation 3:

$$Outcome_i = \beta_0 + \beta_1 \widehat{Physical\ Activity}_i + \beta_2 Mediator_i + \delta' X_i + \epsilon_i \quad (4)$$

ϵ_i is a composite error term that is uncorrelated with the predicted value of physical activity and X_i is the vector of demographic, individual, and family control covariates in the OLS model in equation 1. $Mediator_i$ represents the vector of potential mediating mechanisms that explain the relationship between physical activity and educational attainment.

β_1 in Equation 3, which represents the relationship between physical activity and the outcome, should decrease with the inclusion of mediators in the equation. Second, the relationship between the mediator and the outcome (β_2 in Equation 4) is statistically significant. Lastly, there should be a statistically significant relationship between physical activity and the mediator. To test this last criterion, the fitted value of $\widehat{Physical\ Activity}_i$ from Equation 2 should be used to predict the relationship between physical activity and the mediators:

$$Mediator_i = \beta_0 + \beta_1 \widehat{Physical\ Activity}_i + \delta' X_i + \epsilon_i \quad (5)$$

ϵ_i is a composite error term that is uncorrelated with the predicted value of physical activity and X_i is the vector of demographic, individual, and family control covariates in the OLS model in equation 1. If all three criteria are fulfilled, then there is evidence of a factor or number of potential factors that can explain the mechanisms through which physical activity operates to predict educational attainment (Baron & Kenny, 1986).

Measures

Physical Activity

During the in-home interview in Wave I, adolescents were asked three questions regarding their physical activity: 1) during the past week, how many times did you go roller-blading, roller-skating, skate-boarding, or bicycling? 2) during the past week, how many times did you play an active sport, such as baseball, softball, basketball, soccer, swimming, or football? 3) during the past week, how many times did you go exercise, such as jogging, walking, karate, jumping rope, gymnastics or dancing? Adolescents reported how many times per week they partook in each physical activity (not at all, 1 or 2 times, 3 or 4 times, 5 or more times) and the midpoints of each of these categories were used to convert a categorical variable into a continuous variable for each of these questions. If an adolescent reported 5 or more times, the response was coded as 6 times per week. The sum of the responses to these questions was used to create a composite for adolescent physical activity, which ranged from zero to 18 times per week, with a mean of 6.61 times (Table 1.1). Given the low correlations between the three types of physical activity that range between r = .09 and r = .28 (Table 1.3), the extent of overlap between the three measures of physical activity is minimal.

Educational Attainment

Educational attainment is a heterogeneous process, with the determinants of success in completing high school likely to differ from the determinants of entry into and completion of college or other post-secondary schooling. This is accounted for by estimating separate models for measures of years of completed schooling, high school graduation, college entry, and graduating college, all of which are measured when sample members were between ages 24-32 in

Wave IV of the data. If attainment outcomes were not available between ages 24-32, attainment outcomes from when they were between ages 18-26 from Wave III were used.

Years of completed schooling is a continuous measure while high school graduation, college entry, and graduating college are dichotomous. By Wave IV, the average years of completed schooling was 14.13 and the rate of high school completion averaged 84%, college attendance averaged 73%, and college graduation averaged 27% (Table 1.1).

Covariates

In order to reduce potential bias between physical activity and educational attainment, a number of observable adolescent demographic, family, school, and individual characteristics in the Add Health data was included as covariates in the analysis. An important strength of the Add Health is the depth and breadth of information collected in the parent interview as well as the in-school and in-home surveys. The selection of control variables was driven by the goal of selecting measures that might be confounded with physical education but not a part of the causal mechanism by which physical education might affect educational attainment. A full list of these control measures and their summary statistics is provided in Table 1.2.

Adolescent and maternal background characteristics taken from the Wave I in-school surveys of the adolescents and in-home surveys of the adolescents and their parents that are used as covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status, mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, and if English is spoken at home. Additionally, parents reported their total family income in 1994, and indicated if they were able to pay their bills. They also reported if they received any form of welfare (Social Security or Railroad Retirement, Supplemental Security Income, Aid to Families with Dependent Children, food stamps, unemployment or worker's compensations, or a housing subsidy or public housing). The weight statuses of both parents are also included as covariates.

To reduce bias in the association between physical education and educational attainment caused by health status, self-reports of height and weight were used to determine the weight status (healthy/normal, overweight, obese) of each adolescent. If the adolescent was 20 years old or older at the time of the interview, BMI was calculated and weight status was determined using normal BMI cutoff-points were used. If the adolescent was younger than 20 years old, percentile BMI was calculated by gender and age in months using guidelines provided by the Center for Disease Control.

To best account for educational performance before the start of the study, self-reports of GPA (English, math, humanities, science) from the in-school questionnaire were used as a proxy for prior performance. Additional covariates include if in-home survey was conducted during summer months, and grade fixed effects to account for the chance that adolescents further along in high school (e.g. 12^{th} graders) are more likely to graduate high school than those in younger cohorts (e.g. 9^{th} graders).

Variables used for 2SLS model

Count of Physical Activity Resources within a 3km radius.

The Add Health measures the presence of various physical activity resources situated near respondent residences, denominated by the counts within 3 kilometers of Wave I respondent locations from an adolescent's home to a physical activity location via road network. A 3 kilometers road network radius is the largest radius afforded in the dataset that is considered within walking distance. The radii afforded by the Add Health greater than 3 kilometers (5km and 8km) may be a cumbersome distance for adolescents without bikes, cars, or public transportation. Additionally, larger radii have skewed distributions (Appendix Table 1.1) and the outliers for these radii may bias and provide imprecise estimates for the first stage. Distance was determined by using network measures, or measures that accounted for how far a given physical activity resource is from a respondent's home by following the street network. Physical activity resources include instructional facilities (e.g. dance studios, Karate instruction, ski instruction, etc.), membership facilities (e.g. membership athletic club and gymnasiums, membership golf club, membership racquetball club, etc.), outdoor facilities (e.g. ski lodge, day camp, golf driving range, etc.), parks (e.g. recreational parks), public facilities (e.g. youth center, tennis courts, swimming pool, etc.), public fee facilities (e.g. bowling centers, tennis courts, roller skating rink, etc.), schools (e.g. public senior high school, junior college, private junior high, community college, etc.), and YMCAs. Data regarding physical activity resources are based off of Dun & Bradstreet (D&B) primary Standard Industrial Classification code and keyword searches within the company and trade style fields in 1995 and provided in the Add Health dataset. Summary statistics for physical activity resources in a 3km radius are presented in Table 1.1.

Census Block Group Median Household Income.

The average median household income of all families within a census block group was used as an indicator for a county's socioeconomic status. The data regarding household income is derived from the Census of Population and Housing, 1990: Summary Tape File 3A (STF 3A), which contains data on population and housing characteristics produced from the 1990 Decennial Census, including education. These variables are derived from the 1990 Census long-form questionnaire that approximately 1 in 6 of all housing units in the U.S. received. Thus, data in the STF 3A are sample data that have been weighted by the Census Bureau to represent the total population of the geographic units to which they pertain. To account for potential outliers, the average income in a block group was log transformed. Summary statistics for the log of block group median household income are presented in Table 1.1.

County Crime.

The total number of crimes per 100,000 people in an adolescent's county of residence were used as an indicator of the community environment. Although the total number of crimes in a census block group would have been ideal, total number of crimes per 100,000 people in a county is the smallest aggregate measure of crime available in the Add Health data. Crime data are based primarily on the 1995 Uniform Crime Reporting data, obtained from the National Archive of Criminal Justice Data. In certain instances, data from 1990 through 1994 were used, when a county associated with an Add Health respondent lacked 1995 crime statistics. Summary statistics for county crime are presented in Table 1.1.

Local Government Direct Expenditure on Education per Capita.

The amount per capita of direct expenditure on education by the local government was used as a proxy for parental neighborhood selection factors. Expenditure data is derived from the State and Metropolitan Area Data Book and the County and City Data Book, which are provided by the U.S. Bureau of the Census. Direct education expenditure is the provision or support of schools and other educational facilities and services. These services include transportation, school milk and lunch programs and other cafeterias, as well as health and recreational programs. Summary statistics for local government direct expenditure on education per capita are presented in Table 1.1.

Annual Rainfall.

The total annual snowfall for each Wave I respondent was based on data from the adolescent's nearest climate station in the given year in which physical activity is measured. If the climate station nearest to the respondent had no data on the amount of rainfall, the adolescent was assigned a value of rainfall for the next nearest station with available data. Annual means of rainfall were collected for each adolescent. Summary statistics for annual rainfall are presented in Table 1.1.

Variables used for Mediational Analysis

Days of Missed School due to Health.

During the Wave I in-home survey, respondents were asked how often they missed a day of school due to a health or emotional problem. Respondents reported whether they never missed any days, just a few times, about once a week, almost every day, or every day. Responses were then scaled to a continuous scale to represent the number of school days per month an adolescent missed due to health (never missed any days =0, just a few times=2, about once a week=4, almost every day=15, every day=22). Higher values indicate more days of school missed. Summary statistics are presented in Table 1.1.

Feeling of Happiness.

During the Wave I in-home survey, respondents were asked questions regarding their current emotional state. A scale regarding a respondent's happiness was created from four questions in which respondents affirmed on a four-point scale (never or rarely, sometimes, a lot of the time, most of the time or all of the time). Items consisted of: 1) You felt that you were just as good as other people, 2) You felt hopeful about the future, 3) You were happy, and 4) You enjoyed life. Scores for each item were averaged to create a composite for feelings of happiness (α=.71). Higher values indicate increased feelings of happiness. Summary statistics are presented in Table 1.1.

Feeling of Sadness.

During the Wave I in-home survey, respondents were asked questions regarding their current emotional state. A scale regarding a respondent's sadness was created from six questions in which respondents affirmed on a four-point scale (never or rarely, sometimes, a lot of the time, most of the time or all of the time). Items consisted of: 1) You were bothered by things that usually don't bother you, 2) You felt that you could not shake off the blues, even with help from your family and your friends, 3) You felt depressed, 4) You thought your life had been a failure, 5) You felt lonely, and 6) You felt sad. Scores for each item were averaged to create a composite for feelings of sadness (α=.83). Higher values indicate increased feelings of sadness. Summary statistics are presented in Table 1.1.

Add Health Picture Vocabulary Test (PPVT).

At the beginning of the Wave I in-home survey, respondents were given the Add Health Picture Vocabulary Test, which is a computerized, abridged version of the Peabody Picture Vocabulary Test- Revised (PPVT). In this test, an interviewer reads a word out loud and the respondent selects one of four simple, black-and-white illustrations arranged in a multiple choice format that best fits the meaning of the word. There are 87 items on this test and raw scores were standardized by age. Scores on this abridged PPVT will be used as a proxy for cognition following its use in a number of different studies (Belfort et al., 2013; Freedman, Brown, Shen, & Schaefer, 2015; Magnuson et al., 2016; Nyaradi et al., 2013). Summary statistics are presented in Table 1.1.

Results

Descriptive Statistics

Table 1.1 provides descriptive information for the main predictor variable and outcomes of interest used the analyses and Table 1.2 provides descriptive information on all covariates. On average, the respondents reported that they participated in physical activity 6.61 times per week (standard deviation = 4.27) and by Wave IV, respondents averaged 14.13 years of schooling (standard deviation = 2.23). The sample was 51% female, and in terms of race/ethnicity, the sample was 35% white, 23% black, 20% Hispanic, 9% Asian, and 13% Other. Mothers reported, on average, 13.19 years of schooling (standard deviation = 2.74). 14% of the sample was overweight while 10% of the sample was obese.

Table 1.3 shows the correlations between the main predictor and attainment outcomes. More physical activity in Wave I was positively related to completed schooling, graduating high school, attending college, and graduating college but the correlations are never greater than .10.

OLS Regression Results

The association between adolescent physical activity and the most general measure of educational attainment–years of completed schooling between ages 24-32 was considered in Table 1.4. The first column of Table 1.4 shows estimates from a bivariate regression model between physical activity and years of schooling, without any other predictors. In the absence of any controls, a one standard deviation increase in physical activity, or increasing the number of instances of physical activity by 4.27 times per week, in Wave I is significantly associated with about an additional .118 of a year of completed schooling.

The second model shows estimates from an OLS regression model with a full set of control variables. The physical activity coefficient increases to .132, which indicates that, in the presence of the host of child, family, and other demographic controls, a one standard deviation increase in physical activity is associated with a little more than an eighth of a year increase in completed schooling. Complete OLS regression results are presented in Appendix Table 1.2.

Estimates from logistic regression models predicting high school graduation, attending college, and graduating from college are also presented in Table 1.4 using marginal probability coefficients. Bivariate regression models and OLS models with the full set of controls are reported for each of the three logistic outcomes. Results are also presented in odds-ratios in Appendix Table 1.3. A one-standard deviation increase in physical activity associated with an increase in the probability of graduating high school by 1.6%, attending college by 2.3%, and graduating college by 1.7% when accounting for the full set of controls.

2SLS Regression Model Results

Table 1.5 presents results from the first stage of the 2SLS model in which the instrumental variable (physical activity resources) and conditions (i.e., block group median household income, county crime, local government direct expenditure per capita on education, and annual rainfall) are used to estimate a predicted value for physical activity. A correlation matrix between variables used in the 2SLS model and physical activity in Wave 1 are presented in Appendix Table 1.4. In order for the instrumental variable to be considered a good instrument, one of the main criterion is a statistically significant relation between the instrumental variable and physical activity. Column 1 of Table 1.5 shows that one additional physical activity resource in a 3km network radius around an adolescent's home is associated with a .002 standard deviation increase in physical activity. When adding block group median household income as a condition in Column 2; both block group median household income and county crime in Column 3; and block group median household income, county crime, and local government direct expenditure per capita on education in Column 4; and block group median household income, county crime, local government direct expenditure per capita on education, and annual rainfall as conditions in Column 5, the association between physical activity resources and physical activity remain constant in both magnitude and significance.

Another criterion for a good instrument is for the F-statistic in the reduced form of the 2SLS model to be larger than 10 (Staiger & Stock, 1997). This criterion ensures that the maximum bias in the instrumental variable estimators to be less than 10%. Column 1 of Table 1.5 shows that in the absence of block group median household income, county crime, local government direct expenditure per capita on education, and annual rainfall conditions in the first stage, the F-statistic is 21.91. When including block group median household income, the F-statistic increases to 26.40 (Column 2) and when including county crime, the F-statistic decreases to 16.11 (Column 3). When including local government direct expenditure per capita as an additional condition, the F-statistic decreases to 10.84 (Column 4). In the preferred model, which conditions on block group median household income, county crime, local government direct expenditure per capita on education, and annual rainfall (Column 5), the F-statistic is 11.22. Each of these models exhibit F-statistics greater than the aforementioned cutoff point that would make physical activity resources in a 3km network radius a weak instrument.

Table 1.6 presents 2SLS model results in which a predicted value for physical activity estimated from the first stage equation in Table 1.5 was used to estimate the impact of physical activity on years of completed schooling. Column 1 of Table 1.6 replicates the OLS results from Column 2 in Table 1.4 while Column 2 presents results from the 2SLS model using the count of physical activity resources within an 3km network radius as an instrumental without any other contextual variables but with the full set of covariates from the OLS model. A one-standard deviation increase in physical activity increases in years of completed schooling by 2.729 years but this relationship is only marginally significant at the $p<.10$ level.

When conditioning for block group median household income in the first stage (Column 3), the relationship between physical activity and years of completed schooling is statistically significant and the coefficient for standardized physical activity increases to 3.05. However, conditioning for block group median household income and county total crime in the first stage (Column 4), the coefficient drops to 2.17. When adding local government expenditure per capita on education to the first stage model (Column 5), the coefficient drops further to 2.08. Column 6 presents the results from the preferred model, predicting the impact of standardized physical activity on years of completed schooling. This model shows an additional standard deviation increase in physical activity per week is predictive of an additional 1.54 years of schooling when conditioning for block group median household income, county crime, local government direct expenditure per capita on education, and annual rainfall in the first stage of the 2SLS model.

Table 1.7 presents 2SLS model results in which a predicted value for weekly physical activity estimated from the first stage equation in Table 1.5 was used to estimate the impact of physical activity on discrete measures of educational attainment such as graduating high school or college. Although the outcomes are discrete, the results use an OLS in the second stage of the 2SLS to present linear probabilities. Columns 1, 3, and 5 of Table 1.7 replicate the marginal effects from the logistic regressions results shown in Table 1.4. Columns 2, 4, and 6 presents results from the 2SLS model using the predicted value of physical activity derived from Column 5 of Table 1.5 and the full set of covariates for high school graduation, attending college, and graduating college, respectively. Results from the preferred model show a standard deviation increase in physical activity increases the probability of attending college and graduating college by 26.1 and 26.6 percentage points, respectively. An increase in physical activity also shows a marginally significant relationship with the probability of graduating high school of 10.4 percentage points.

Table 1.8 explores the extent to which different factors can potentially mediate the relationship between physical activity and years of completed schooling using the 2SLS model. Following the Baron and Kenny (1986) approach to identifying mediators, the models in this table includes mediators to the second stage of the preferred 2SLS model (Column 6 of Table 1.6) and examines the extent to which the magnitude of the original relationship between physical activity and years of completed schooling is reduced. Column 1 replicates the results from Column 6 of Table 1.6 while Columns 2-5 include one mediator (e.g., days of school missed, feelings of happiness, etc.) to the second stage of the 2SLS model. The inclusion of days of school missed due to health, feelings of happiness, and feelings of sadness to the model do not significantly impact the relationship between physical activity and years of schooling. However, when including the Add Health Picture Vocabulary Test (PPVT), the coefficient for the relationship between physical activity and years of schooling drops from 1.54 to 1.09. When including all four mediators into the second stage (Column 6 of Table 1.8), there is not much of a difference in the coefficient for physical activity between the models with just PPVT scores or with all four mediators (i.e., 1.09 vs. 1.06). Each of these models also show F-statistics greater than 10.

Furthermore, the association between PPVT and years of completed schooling is found to be statistically significant, fulfilling the second criterion of mediation. A standard deviation increase in PPVT scores is associated with an increase in years of completed schooling by .55

years (Column 5 of Table 1.8). In the model that includes all the mediators (Column 6 of Table 1.8), a standard deviation increase in PPVT scores is associated with a .54 increase in years of completed schooling.

Table 1.9 presents the results for the final criterion of mediation—a statistically significant relationship between physical activity and the mediators. The models use the predicted value for weekly physical activity estimated from the first stage equation in Table 1.5 to predict each of the four mediators. Results from the second stage of the 2SLS models indicate the only statistically significant causal relationship to be the one between physical activity and PPVT scores. A standard deviation increase in physical activity increases PPVT scores by .86 of a standard deviation. It is also important to note that the F-statistic for this model using the preferred first stage estimates is 12.14. As such, PPVT fulfills all three criteria required to be considered a mediator between physical activity and years of completed schooling and accounts for roughly a third of the relationship between physical activity and years of completed schooling.

Robustness Checks

A potential threat to the general conclusion are heterogeneous associations by race, gender, income, and health. To test for potential differential associations, interaction terms between physical activity and race, gender, income, and weight status were included to the preferred OLS model in Table 1.4 (Appendix Table 1.2). Column 3 of Appendix Table 1.2 shows that the associations between physical activity and years of completed schooling do not vary by gender. Interactions between physical activity and race/ethnicity show that black adolescents may not benefit from physical activity relative to white adolescents and deserves further inspection (Appendix Table 1.2, Column 5). There is also no evidence of differential associations by total family income and weight status (Appendix Table 1.2, Column 6 and 7).

Additionally, based on the initial sampling in Add Health and the outcomes of interest, one may argue that there may be heterogeneous impacts by grade—an adolescent who is in grade 12 has greater odds of graduating high school relative to an adolescent in grade 7 because they are closer to graduating. To this end, interaction terms between physical activity and grade in Wave I were added to the preferred OLS model in Table 1.4. These interactions show that 9^{th} and 12^{th} graders may benefit more from physical activity relative to 7^{th} graders and further inspection is needed (Appendix Table 1.2, Column 4).

Another potential concern is the use of census block median household income as a measure for socioeconomic status in the first stage of the 2SLS model. Add Health provides additional measures for socioeconomic status, such as median household income by tract group, as well as median family income by block and tract group. Each of these measures were similarly log-transformed to account for outliers. Descriptive statistics for these different specifications are presented in Appendix Table 1.1. First stage regression estimates found in Appendix Table 1.5 show that block group median household income, tract group median household income, block group median family income, and tract group median family income are all significantly associated with physical activity and provide similar coefficients. Furthermore, the F-statistics using these three substitutes (ranging from 10.76 to 14.68) demonstrate a strong first stage estimate and are comparable to the F-statistic of the preferred model of 11.22. Appendix Table 1.6 shows estimates using each of these measures of neighborhood socioeconomic status in lieu of block group median household income in the first stage. Using any of these four measures of neighborhood socioeconomic status does not substantially change the estimates initially provided in the preferred 2SLS model (Column 5 of Table 1.6).

An additional robustness check lies with different specifications for the physical activity counts in a 3km radius. The preferred model uses a network radius, which measures the distance from an adolescent's home to a physical activity location via road network. Alternative measures include a Euclidean radius and weighted network and Euclidean radii. A Euclidean radius is the straight-line distance, regardless of road network, from an adolescent's home to a physical activity location. Weighted counts are used to account for instances where there are zero physical activity counts within a given radius. In weighted counts, if the distance from an adolescent's home and physical activity resource was less than or equal to one kilometer, the count weight equaled one. If the resource distance was greater than one kilometer, the count weight equaled one divided by the distance in kilometers. Descriptive statistics for these different specifications are presented in Appendix Table 1.4. First stage regression estimates using these different 3km physical activity specifications in Appendix Table 1.7 show that each of these different specifications are significantly associated with physical activity and produce similar coefficients. Furthermore, the F-statistics using these three substitutes (ranging from 10.21 to 11.68) demonstrate a strong first stage estimate and are similar to the original F-statistic of 11.22. Appendix Table 1.8 shows estimates using each of these radii instead of the unweighted network radius in the first stage of the 2SLS model. Using these different radii provide similar estimates to those initially provided in Column 5 of Table 1.6 as each of these radii provide estimates slightly greater than 1.50 years.

In addition to different 3km radius specifications, counts of physical activity in different radii sizes allotted by the Add Health can be used—namely 1km, 5km, and 8km network radius and 3km, 5km, and 8km weighted network radius (summary statistics provided in Appendix Table 1.1). First stage regression estimates using these different radii physical activity specifications in Appendix Table 1.9 show a significant relationship between physical activity resources and physical activity. When considering the different specifications that demonstrate strong instruments based on their F-statistics (1km network radius and 3km weighted network radius), the 2SLS estimates for each of these radii (Columns 2, 3, and 5 of Appendix Table 1.10) show similar estimates to the preferred model using physical activity counts in Table 1.6.

When extending the physical activity counts in the network radius to 5km or 8km or the weighted network radius to 8km, the F-statistic drops below 10 (9.62, 8.17, 9.39, respectively). The different network radii specifications are not as strong as an instrument as the 3km unweighted network radius—perhaps due to the outliers at 5km or 8km (Appendix Table 1.1) or the fact that including resources that are further than 3km from an adolescents' home is too far to produce a good estimate for physical activity. However, these models show similar estimates to the preferred model in Column 5 of Table 1.6.

A potential threat to the general conclusion is the skew found in the count of physical activity resources in a 3km network radius (Table 1.1). It is possible that the significance between physical activity resources and physical activity is driven by outliers. To account for outliers, the number of physical activity resources in a 3km network radius was truncated to the 99^{th} percentile, which decreases the maximum number of counts from 210 to 106. When truncating to the 99^{th} percentile, the number of physical activity resources is still significantly associated with physical activity. The F-statistics are all greater than the cutoff of 10 when including the conditions in the first stage of the 2SLS models—ranging from 10.63 to 26.34

(Columns 2-5 in Appendix Table 1.11). The coefficients in the 2SLS models when using the number of physical activity resources truncated to the 99th percentile are also fairly consistent to those from the non-truncated models with conditions in the first stage of the 2SLS models, particularly in the preferred model (Column 5 of Appendix Table 1.12).

The number of physical activity resources in a 3km network was truncated to the 90th percentile, which decreases the maximum number of counts from 210 to 33. When truncating to the 90th percentile, the number of physical activity resources is still significantly associated with physical activity (Appendix Table 1.13). Furthermore, the F-statistic for the preferred model is still greater than the cutoff of 10 at 10.18 (Column 5 of Appendix Table 1.13). The 2SLS estimates using this truncated variable in Appendix Table 1.14 show a slightly smaller same estimate as the preferred 2SLS model in Column 6 of Table 1.6.

To further test the results of the main model, a falsification test was employed to assess the extent to which physical activity resources and not other neighborhood factors are good predictors for adolescent physical activity in the first stage of the 2SLS model. One may argue that the number of physical activity resources are a function of and is a proxy for neighborhood wealth. If physical activity is a proxy for neighborhood wealth, then the counts of other resources that are reflective of wealthier neighborhoods that are not intended to improve physical activity would also be also be statistically associated with the amount of physical activity adolescents participate in.

The extent to which the count of physical *inactivity* resources in a 3km network radius, such as movie theaters, video game arcades, or amusement arcades, predict physical activity in the first stage of the 2SLS model was used as a falsification test. The number of physical *inactivity* resources was taken from the same database used to determine the counts of physical activity resources in a 3km network radius. If these *inactivity* resources prove to be a statistically significant instrument, the number of physical activity resources can be considered a poor instrument and a reflection of another factor that is not in the model specification, such as neighborhood wealth. The first stage regressions where the number of inactivity resources was used in lieu of physical activity resources as an instrument find physical inactivity resources to not be associated with physical activity (Appendix Table 1.15). Furthermore, the small F-statistics confirm that these inactivity resources prove to be a poor instrument to estimate a predicted value for adolescent physical activity. Appendix Table 1.16 shows that when using physical *inactivity* resources as an instrument, the estimated impact of an additional standard deviation of physical activity is imprecise.

Discussion

Drawing data from the National Longitudinal Study of Adolescent Health, this study finds a causal link between adolescent physical activity and educational attainment in adulthood using quasi-experimental methods—a standard deviation increase in weekly physical activity increases years of completed schooling by 1.54 years and increases the probability of attending college and graduating from college by 26.1% and 26.6%, respectively. This relationship was also found to be partially mediated by improvements in cognition.

When considering the impact of physical activity on years of completed schooling, it is important to consider a number of factors that potentially explain this large coefficient. Although instrumental variables can be used to estimate an unbiased or causal estimate of adolescent weekly physical activity on years of completed schooling, this estimate is only relevant across certain populations of adolescents. When considering any sort of educational policy to increase physical activity, the biggest issue lies with "noncompliance." It is hard to imagine that this type of policy would be beneficial for adolescents who enjoy physical activity—they would likely partake in physical activity regardless of any policy changes.

In line with this "noncompliance" issue when using instrumental variables, it is important to consider that the population who would be exposed to a given policy fall into one of four potential groups: 1) "always-takers" or individuals who would participate in physical activity regardless of changes in policy; 2) "never-takers" or individuals who would find a way to *not* participate in physical activity regardless of changes in policy; 3) "compliers" or individuals who would partake in physical activity if they were affected by policy changes and would not partake in physical activity if they were not affected by policy changes; or 4) "defiers" or individuals who would partake in physical activity if they were not affected by policy changes but would partake in physical activity if they were not affected by policy changes. The unbiased estimate obtained using instrumental variables is considered the "local average treatment effect" and this estimate is only applicable for "compliers," or individuals whose behaviors would change as a function of a certain policy. The impact of physical activity on years of completed schooling is unknown outside of this group and it is possible that the compliers make up a very small portion of the population. Future work may profitably explore who these "compliers" are and identify roughly how much of the population would benefit from policy changes to increase adolescent physical activity.

Another important consideration is the size of the standard error of .64—which gives fairly large 95% confidence interval of .29 years to 2.79 years. Along those lines, the "true" effect of physical activity on years of schooling may lie closer to .29 years than the estimated coefficient of 1.54 years.

It is also important to note the relatively large standard deviation of years of completed schooling in Table 1.2. Converting this unstandardized coefficient to a standardized coefficient converts the coefficient of 1.54 years into an effect size of .69. Regrettably, there is no true-experimental study that examines the long-term benefits of physical activity to compare this finding to. The best comparison may be experimental studies that examine academic achievement (e.g. grades, achievement tests) as an outcome. An effect size of .69 is within the range of effect sizes of true-experimental design studies [.00-1.49] used by Sibley and Etnier (2003) in their review of small experimental studies examining the link between physical activity and cognition or academic performance in children.

In addition to the standard deviation of the outcome variable, it is also important to consider the size of the standard deviation of the predictor variable or the "dosage" of physical activity. A standard deviation increase in physical activity is equivalent to participating in physical activity (e.g., biking, playing sports, exercising) 4.27 more times per week. The physical activity interventions reviewed by Howie and Pate (2012) ranged in duration from 5 minutes of exercise to 90 minutes of physical activity per week and the interventions reviewed by Tomporowski, Davis, Miller, and Naglieri (2008) ranged from 20 days to the academic year. Furthermore, the types of physical activity interventions ranged from balance and coordination to strength training to enhanced school physical education to aerobic running, among others. Given the results of these reviews, the results from this study can be considered within some of the established findings involving physical activity and short term academic outcomes.

Sibley and Etnier (2003) include a study by Zervas, Danis, and Klissouras (1991) in which nine pairs of monozygotic twin boys (ages 11-14 years) were randomly divided into two treatment groups and compared against a third control group of boys. All three groups were administered the Cognitrone Test pretest, which was designed to test mental performance. Following this test, treatment group participants performed on the treadmill for 20 minutes at a running speed intensity above their individual anaerobic thresholds. An hour following the pretest, all three groups were assessed again. The average improvement for the treatment groups relative to the control group was an effect size of .16.

A more recent 2-year experimental study examining the benefits of physical activity on academic performance uses 759 fourth and fifth grade children divided into three groups—two of which given an additional three days per week of additional 30-minute physical education classes relative to the control group. Relative to the control group, the treatment groups scored higher on a standardized achievement test on a battery of English assessments with average effect size of .17 (Sallis et al., 1999).

However, the difference between these effect sizes and the effect size reported in this study can perhaps be explained by differences in physical activity. A standard deviation increase in physical activity as used in this analysis may be greater in both intensity and duration than those used in prior studies, which examined the impact of physical activity on short-term educational outcomes. For example, the physical activity intervention in Sallis et al. (1999) increases the amount of physical activity by only 1.5 hours per week, which can be significantly less than the 4.27 times per week reported in this analysis.

It is also important to note that an effect size of the relationship between adolescent physical activity and educational attainment is being compared with an effect size of the relationship between physical activity and educational achievement in childhood. Habitual physical activity in adolescence may have a larger impact on eventual educational attainment than childhood physical activity on near-term educational achievement. It is possible that habitual physical activity in adolescence changes an individual's behaviors and teaches lessons such as time management, which is autonomous in nature and can have long-lasting impacts relative to increases in physical activity in childhood that are dictated by adults.

From a policy standpoint, it may also be very difficult to find ways within schools or public programs to increase adolescent physical activity by 4.27 times per week. Potential policy-related changes such as increases in required physical education classes in high school would likely taken the form of one or two more instances of physical activity per week. Along those lines, the preferred model estimates suggests that participating in physical activity one more time per week is equivalent to an increase in years of completed schooling by .36 years. Future research should seek to examine the academic benefits of school policies to increase physical activity.

In addition to understanding the magnitude of the impact of physical activity on educational attainment, mediational analysis shows that a significant amount of the relationship can be explained by improvements in cognition. Under the assumption that the relationship between PPVT and years of completed schooling is causal, the sum of the coefficients between physical activity and years of schooling (1.09) and between the measure of cognition used in this study and years of schooling (.55) is almost equivalent to the original relationship between physical activity and years of schooling (1.54—Column 1 of Table 1.8). In other words, cognition mediates about 30% of the relationship between physical activity and years of completed schooling.

Based on neuroimaging studies of physical activities, physical activity is related to differences in cognitive function (Hillman et al., 2008; Kramer & Erickson, 2007) and brain structure (Colcombe et al., 2006; Pereira et al., 2007). This can be especially important for adolescents as the brain undergoes significant structural change during adolescence (Giedd et al., 1999). It is possible that increases in physical activity in adolescents can stimulate additional development in the brain during development. This increased development can result improving cognitive ability, which can increase the probability of attending college and graduating from college. Future research examining the academic benefits of physical activity should also seek to examine neurological changes as a potential mediating mechanism.

In sum, adolescent physical activity is a neglected, but significant predictor of later academic achievement. As the focus on academic performance in schools has increased, time allotted to physical activity opportunities in schools have been reduced to promote more instruction time for subjects such as mathematics and language arts, at the expense of other subjects such as physical education classes (Centers for Disease Control and Prevention, 2010; Institute of Medicine, 2013). These movements to reduce physical activity in junior high and high schools, such as reducing physical education classes and cutting funding for extracurricular sports programs, may have adverse impacts of educational achievement. It may be possible that some of the benefits of additional time for mathematics and language arts are being mitigated by decreases in physical activity. Quasi-experimental estimates using instrumental variables show significant and substantial impacts of physical activity on educational achievement and future work should both replicate and extend the findings of this paper.

Table 1.1
Summary Statistics: Main Predictor, Mediators, and Outcome Variables

	Mean/%	Std. Dev	Min	Max
Predictor Variables (Wave I)				
Total Physical Activity	6.61	4.27	.00	18.00
Biking[&]	1.09	1.77	.00	6.00
Sports[&]	2.53	2.30	.00	6.00
Exercise[&]	2.99	2.18	.00	6.00
Outcome Variables				
Wave IV Attainment				
Highest Grade Completed	14.13	2.23	8.00	22.00
Graduate High School	84.32%			
Attend College	72.85%			
Graduate College	26.69%			
Instrumental Variable				
Physical Activity Resources in a 3km network radius	14.2479	19.9524	0.00	315.00
Instrumental Variable Conditions				
log[Block Group Median Household Income (in $10,000)]	1.04	.48	-0.69	2.70
County Crime	5.71	2.69	0.11	13.72
Local Government Direct Expenditure on Education per Capita	673.64	158.65	2.54	2281.68
Annual Rainfall	37.85	15.18	3.11	91.00
Mediator Variables				
Days of School Missed due to Health	.95	2.09	.00	22.00
Feelings of Happiness	1.99	.68	.00	3.00
Feelings of Sadness	.46	.51	.00	3.00
Add Health Picture Vocabulary Test (PPVT)	98.60	15.48	9.00	141.00

[&]Used to create composite total physical activity

Table 1.2
Summary Statistics: Covariates

	Mean/%	Std. Dev	Min	Max
Female	50.59%			
Race				
Hispanic	19.65%			
Black	22.88%			
Asian	8.91%			
Other	13.43%			
US born	90.02%			
Parents US born	82.24%			
Live with both parents	70.20%			
English spoken at home	88.48%			
Mother's Education	13.19	2.74	.00	20.00
Self-reports of GPA at Wave I				
English	2.83	.97	1.00	4.00
Math	2.74	1.02	1.00	4.00
Humanities	2.88	1.00	1.00	4.00
Science	2.84	1.01	1.00	4.00
Mother's age at birth	25.24	5.34	13.00	54.00
Birth weight (lb)	7.22	1.41	3.00	12.00
1994 log(total family income)	3.52	.82	.00	6.91
Can't pay bills	19.01%			
Welfare recipient	28.69%			
Mother is obese	17.69%			
Father is obese	9.78%			
Grade in Wave I				
7th	13.70%			
8th	13.33%			
9th	17.85%			
10th	19.65%			
11th	18.94%			
12th	16.52%			
Parents' marital status in Wave I				
Married	70.20%			
Single/Never Married/Widowed/Separated	14.98%			
Divorced	14.83%			
Weight Status				
Normal/Healthy	75.82%			
Overweight	13.83%			
Obese	10.35%			

Table 1.3
Correlation Matrix between Predictors and Outcome Variables

	(1)	(2)	(3)	(4)	(5)
Attainment (Wave IV)					
Years of Completed Schooling	1.00				
Graduate High School	.46***	1.00			
Attend College	.72***	.42***	1.00		
Graduate College	.80***	.26***	.40***	1.00	
Physical Activity (Wave I)	.05***	.03***	.04***	.05***	1.00

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.4:
Educational Attainment in Wave IV Regressed on Physical Activity (OLS)

	Highest Grade Completed		Graduate High School[&]		Attend College[&]		Graduate College [&]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Predictor Variable (Standardized)								
Physical Activity	.118***	.132***	.012***	.016***	.018***	.023***	.023***	.017***
(Wave I)	(.027)	(.018)	(.003)	(.002)	(.005)	(.004)	(.005)	(.004)
Covariates Included?	No	Yes	No	Yes	No	Yes	No	Yes
Constant	14.130***	6.528***						
	(.084)	(.257)						
R^2	.003	.306						
Observations	17457	17197	17461	17197	17457	17196	17464	17200

Note. Standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$
[&]Results reported as marginal effects from a logistic regression.

Table 1.5
First Stage Regressions for 2SLS Model
Physical Activity (Wave I) Regressed on Instrumental Variables

	Standardized Physical Activity (Wave I)				
	(1)	(2)	(3)	(4)	(5)
Instrumental Variables					
Physical Activity Resources in a 3km network radius	.0022***	.0023***	.0025***	.0024***	.0024***
	(.0004)	(.0004)	(.0004)	(.0004)	(.0004)
log[Block Group Median Household Income (in $10,000)]		.1199***	.1148***	.1113***	.1017***
		(.0232)	(.0241)	(.0238)	(.0247)
County Crime			-.0109*	-.0103*	-.0097+
			(.0051)	(.0051)	(.0051)
Local Government Direct Expenditure on Education per Capita				.0001	.0000
				(.0001)	(.0001)
Annual Rainfall					-.0013
					(.0008)
Covariates Included?	Yes	Yes	Yes	Yes	Yes
Constant	-.0600	-.0555	.0055	-.0635	.0186
	(.0909)	(.0954)	(.0941)	(.1170)	(.1319)
R^2	.1150	.1166	.1173	.1175	.1178
F-Statistic	21.9138	26.4020	16.1098	10.8362	11.2168
Observations	19971	19129	19129	19129	19129

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 1.6:
Years of Completed Schooling in Wave IV Regressed on Physical Activity (2SLS)

	OLS	2SLS with Count of Physical Activity Resources in a 3km network				
		With covariates only	Plus block group median household income	Plus county crime	Plus local government education expenditure per capita	Plus annual rainfall
	(1)	(2)	(3)	(4)	(5)	(6)
Predictor Variable (Standardized)						
Physical Activity	.132***	2.729+	3.053***	2.170***	2.083***	1.542*
(Wave I)	(.018)	(1.477)	(.766)	(.583)	(.600)	(.638)
Covariates Included?	Yes	Yes	Yes	Yes	Yes	Yes
Constant	6.528***	6.590***	6.663***	6.627***	6.624***	6.602***
	(.257)	(.315)	(.341)	(.289)	(.285)	(.265)
R^2	.306	.118	.119	.120	.120	.121
F-Statistic		21.914	2 6.402	16.110	10.836	11.217
Observations	17197	17197	16509	16509	16509	16509

Note. Standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 1.7:
Schooling Outcomes in Wave IV Regressed on Physical Activity (2SLS)

	Graduate High School		Attend College		Graduate College	
	OLS	2SLS[&]	OLS	2SLS[&]	OLS	2SLS[&]
	(1)	(2)	(3)	(4)	(5)	
Predictor Variable (Standardized)						
Physical Activity	.016***	.104+	.023***	.261**	.017***	.266*
(Wave I)	(.002)	(.055)	(.004)	(.097)	(.004)	(.123)
Covariates Included?	Yes	Yes	Yes	Yes	Yes	Yes
Constant		.314***		0.254***		1.154***
		(0.050)		(0.056)		(0.052)
R^2		.121		.121		.121
F-Statistic		11.366		11.217		11.254
Observations	17197	16509	17196	16509	17200	16509

Note. Standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$
[&]2SLS uses preferred first stage estimates of Column 5 on Table 1.7 using count of physical activity resources in a 3km network as an instrument.

Table 1.8:
Years of Completed Schooling in Wave IV Regressed on Physical Activity with Mediators (2SLS)

	(1)	(2)	(3)	(4)	(5)	(6)
Predictor Variable (Standardized)						
Physical Activity	1.542* (.638)	1.556* (.628)	1.406* (.622)	1.539* (.624)	1.088* (.457)	1.056* (.437)
Mediator Variables (Standardized)						
Days of School Missed due to Health		-.127*** (.021)				-.110*** (.018)
Feelings of Happiness			.071 (.069)			-.015 (.054)
Feelings of Sadness				-.140*** (.025)		-.105*** (.020)
Add Health Picture Vocabulary Test (PPVT)					.547*** (.032)	.536*** (.033)
Covariates Included?	Yes	Yes	Yes	Yes	Yes	Yes
Constant	6.602*** (.265)	6.618*** (.267)	6.667*** (.270)	6.640*** (.262)	8.106*** (.217)	8.099*** (.215)
R^2	.121	.121	.130	.121	.121	.131
F-Statistic	11.217	11.098	10.362	11.218	11.618	11.398
Observations	16509	16464	16500	16499	15724	15670

Note. Standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
$^{\&}$2SLS uses preferred first stage estimates of Column 5 on Table 1.7 using count of physical activity resources in a 3km network as an instrument.

Table 1.9:
Mediators in Wave I Regressed on Physical Activity (2SLS)

	Days of School missed due to health	Feelings of Happiness	Feelings of Sadness	Add Health Picture Vocabulary Test (PPVT)
Predictor Variable (Standardized)				
Physical Activity	.183	-.067	.086	.858*
	(.159)	(.200)	(.150)	(.343)
Covariates Included?	Yes	Yes	Yes	Yes
Constant	.131	-.926***	.208**	-2.835***
	(.093)	(.124)	(.077)	(.134)
R^2	.118	.118	.118	.118
F-Statistic	12.576	12.700	12.680	12.141
Observations	19066	19115	19113	18204

Note. Standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
[&]2SLS uses preferred first stage estimates of Column 5 on Table 1.7 using count of physical activity resources in a 3km network as an instrument.

Appendix Table 1.1
Summary Statistics for Instrumental Variables in 2SLS Model Used in Robustness Checks

	Mean/%	Std. Dev	Min	Max
Instrumental Variables				
Physical Activity Resources in a 3km network radius	10.61	9.47	0.00	25.00
Physical Activity Resources in a 3km Euclidean radius	21.69	27.81	0.00	467.00
Weighted Physical Activity Resources in a 3km network radius	8.20	11.34	0.00	153.71
Weighted Physical Activity Resources in a 3km Euclidean radius	12.70	15.99	0.00	241.12
Physical Activity Resources in a 1km network radius	1.89	2.99	0.00	58.00
Physical Activity Resources in a 5km network radius	36.08	50.57	0.00	723.00
Physical Activity Resources in a 8km network radius	86.07	122.64	0.00	1412.00
Weighted Physical Activity Resources in a 5km network radius	13.67	18.73	0.00	260.27
Weighted Physical Activity Resources in a 8km network radius	21.39	29.38	0.00	356.13
Physical Inactivity Resources in a 3km network radius	.55	1.10	0.00	38.00
Conditions				
log[Tract Group Median Household Income (in $10,000)]	2.994	1.246	0.50	12.51
log[Block Group Median Family Income (in $10,000)]	3.517	1.479	0.50	15.00
log[Tract Group Median Family Income (in $10,000)]	3.410	1.346	0.50	13.28

Appendix Table 1.2:
Highest Grade Completed in Wave IV Regressed on Physical Activity (OLS)

	Highest Grade Completed (Wave IV)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Predictor Variable (Standardized)							
Physical Activity	.118***	.132***	.132***	.083*	.174***	.152***	.138***
(Wave I)	(.027)	(.018)	(.021)	(.037)	(.025)	(.041)	(.020)
Covariates							
Female		.522***	.522***	.524***	.518***	.522***	.522***
		(.029)	(.029)	(.029)	(.029)	(.029)	(.029)
Grade in Wave I							
8^{th}		.118*	.118*	.121*	.114*	.117*	.117*
		(.052)	(.052)	(.056)	(.052)	(.052)	(.052)
9th		.265***	.264***	.241**	.261***	.264***	.264***
		(.073)	(.073)	(.076)	(.073)	(.073)	(.073)
10th		.511***	.511***	.495***	.511***	.510***	.511***
		(.082)	(.082)	(.083)	(.081)	(.082)	(.082)
11th		.632***	.632***	.610***	.633***	.631***	.633***
		(.087)	(.088)	(.088)	(.087)	(.087)	(.087)
12th		.884***	.884***	.901***	.884***	.884***	.885***
		(.095)	(.096)	(.101)	(.095)	(.095)	(.095)
Race/Ethnicity							
Hispanic		-.157**	-.157**	-.157**	-.154**	-.157**	-.157**
		(.055)	(.055)	(.055)	(.055)	(.055)	(.055)
Black		.136^{+}	.136^{+}	.136^{+}	.133^{+}	.135^{+}	.135^{+}
		(.077)	(.077)	(.077)	(.077)	(.077)	(.077)
Asian		-.044	-.044	-.044	-.039	-.044	-.043
		(.152)	(.152)	(.151)	(.152)	(.151)	(.151)
Other		-.178***	-.178***	-.180***	-.179***	-.179***	-.178***
		(.043)	(.043)	(.043)	(.042)	(.043)	(.043)
US born		.044	.044	.044	.045	.043	.045
		(.088)	(.088)	(.088)	(.088)	(.088)	(.088)
Parents US born		-.345***	-.345***	-.343***	-.347***	-.345***	-.347***
		(.097)	(.097)	(.096)	(.098)	(.097)	(.097)
Live with both parents		.164***	.164***	.161***	.166***	.164***	.165***
		(.048)	(.048)	(.048)	(.047)	(.048)	(.048)
English spoken at home		-.270**	-.270**	-.271**	-.269**	-.271**	-.270**
		(.084)	(.084)	(.083)	(.085)	(.084)	(.084)
Mother's Education		.186***	.186***	.186***	.186***	.186***	.186***
		(.012)	(.012)	(.012)	(.012)	(.012)	(.012)
Self-reports of GPA at beginning of school year							
English		.260***	.260***	.261***	.260***	.260***	.260***
		(.026)	(.026)	(.026)	(.026)	(.026)	(.026)
Math		.222***	.222***	.223***	.222***	.222***	.222***
		(.022)	(.022)	(.022)	(.022)	(.022)	(.022)
Humanities		.280***	.280***	.280***	.278***	.280***	.280***
		(.027)	(.027)	(.027)	(.027)	(.027)	(.027)

Appendix Table 1.2 (Continued):
Highest Grade Completed in Wave IV Regressed on Physical Activity (OLS)

Science	.207***	.207***	.206***	.208***	.208***	.207***
	(.026)	(.026)	(.026)	(.026)	(.026)	(.026)
Mother's age at birth	.045***	.045***	.045***	.045***	.045***	.045***
	(.004)	(.004)	(.004)	(.004)	(.004)	(.004)
Birth weight (lb)	.016	.016	.016	.016	.016	.016
	(.014)	(.014)	(.014)	(.014)	(.014)	(.014)
log(total family income in1994)	.381***	.381***	.381***	.380***	.382***	.381***
	(.033)	(.033)	(.033)	(.033)	(.034)	(.033)
Can't pay bills	-.114*	-.114*	-.113*	-.113*	-.114*	-.114*
	(.047)	(.047)	(.047)	(.047)	(.047)	(.047)
Welfare recipient	-.231***	-.231***	-.232***	-.230***	-.231***	-.231***
	(.047)	(.047)	(.047)	(.047)	(.047)	(.047)
Mother is obese	-.130**	-.130**	-.131**	-.128**	-.130**	-.130**
	(.046)	(.047)	(.047)	(.047)	(.046)	(.046)
Father is obese	.071	.071	.070	.072	.071	.070
	(.056)	(.056)	(.056)	(.056)	(.056)	(.056)
Parents' marital status						
Single/never married /widowed/separated	.079	.079	.077	.081	.079	.080
	(.049)	(.049)	(.049)	(.049)	(.049)	(.049)
Divorced	-.004	-.004	-.003	-.003	-.005	-.004
	(.053)	(.053)	(.053)	(.053)	(.053)	(.053)
Weight status						
Overweight	-.182***	-.182***	-.183***	-.182***	-.182***	-.182***
	(.040)	(.040)	(.040)	(.040)	(.040)	(.040)
Obese	-.166*	-.166*	-.166*	-.168*	-.166*	-.171*
	(.067)	(.067)	(.066)	(.066)	(.067)	(.066)
Survey Taken in Summer	-.015	-.015	-.016	-.016	-.015	-.015
	(.033)	(.033)	(.033)	(.033)	(.033)	(.033)
Interactions						
Gender						
Physical Activity X Female		-.002				
		(.036)				
Grade						
Physical Activity X Grade 8			-.019			
			(.044)			
Physical Activity X Grade 9			.116*			
			(.049)			
Physical Activity X Grade 10			.042			
			(.051)			
Physical Activity X Grade 11			.011			
			(.048)			
Physical Activity X Grade 12			.144*			
			(.065)			

Appendix Table 1.2 (Continued):
Highest Grade Completed in Wave IV Regressed on Physical Activity (OLS)

Race/Ethnicity							
Physical Activity X Hispanic					-.014		
					(.047)		
Physical Activity X Black					-.140***		
					(.039)		
Physical Activity X Asian					-.057		
					(.049)		
Physical Activity X Other					-.043		
					(.049)		
Income							
Physical Activity X log(Total family income in 1994)						-.008	
						(.011)	
Weight Status							
Physical Activity X Overweight							.013
							(.041)
Physical Activity X Obese							-.078^{+}
							(.043)
Constant	14.130***	6.528***	6.528***	6.544***	6.540***	6.526***	6.532***
	(.084)	(.257)	(.257)	(.258)	(.257)	(.258)	(.257)
R^2	.003	.306	.306	.306	.306	.306	.306
Observations	17457	17197	17197	17197	17197	17197	17197

Note. Robust standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 1.3:
Schooling Outcomes in Wave IV Regressed on Physical Activity (Odds Ratio)

	Highest Grade Completed		Graduate High School[&]		Attend College[&]		Graduate College [&]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Predictor Variable (Standardized)								
Physical Activity	.118***	.132***	1.093***	1.166***	1.095***	1.158***	1.114***	1.117***
(Wave I)	(.027)	(.018)	(0.026)	(0.027)	(0.027)	(0.027)	(0.028)	(0.028)
Covariates Included?	No	Yes	No	Yes	No	Yes	No	Yes
Constant	14.130***	6.528***						
	(.084)	(.257)						
R^2	.003	.306						
Observations	17457	17197	17461	17197	17457	17196	17464	17200

Note. Exponentiated coefficients. Standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$
[&]Logistic regression results reported as odds ratio

Appendix Table 1.4
Correlation Matrix for Instrumental Variables in 2SLS Model and Physical Activity

	(1)	(2)	(3)	(4)	(5)	(6)
Physical Activity (Wave I)	1.00					
Instrumental Variables						
Physical Activity Resources in a 3km network radius	.01	1.00				
log[Block Group Median Household Income (in $10,000)]	.06***	.01	1.00			
County Crime	-.05***	.34***	-.14***	1.00		
Local Government Direct Expenditure on Education per Capita	.02**	.12***	.10***	-.09***	1.00	
Annual Rainfall	-.02**	-.25***	-.29***	.10***	-.29***	1.00

* $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 1.5:
First Stage Regressions for 2SLS Model
Physical Activity (Wave I) Regressed on Instrumental Variables

	Standardized Physical Activity (Wave I)			
	(1)	(2)	(3)	(4)
Instrumental Variables				
Physical Activity Resources in	$.002^{***}$	$.002^{***}$	$.002^{***}$	$.002^{***}$
a 3km network radius	(.000)	(.000)	(.000)	(.000)
log(Block Group Median	$.102^{***}$			
Household Income)	(.025)			
log(Tract Group Median		$.126^{***}$		
Household Income)		(.029)		
log(Block Group Median			$.127^{***}$	
Family Income)			(.028)	
log(Tract Group Median				$.139^{***}$
Family Income)				(.033)
County Crime	$-.010^{+}$	$-.010^{+}$	$-.009^{+}$	$-.009^{+}$
	(.005)	(.005)	(.006)	(.005)
Local Government Direct	.000	.000	.000	.000
Expenditure on Education per Capita	(.000)	(.000)	(.000)	(.000)
Annual Rainfall	-.001	-.001	-.001	-.001
	(.001)	(.001)	(.001)	(.001)
Covariates Included?	Yes	Yes	Yes	Yes
Constant	.019	.005	.010	-.011
	(.132)	(.137)	(.134)	(.140)
R^2	.118	.118	.119	.119
F-Statistic	11.217	10.952	14.680	10.758
Observations	19129	19768	17905	19751

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 1.6:
Years of Completed Schooling in Wave IV Regressed on Physical Activity (2SLS)

	Years of Completed Schooling			
	Preferred Model Using Block Group Median Household Income (Column 5 of Table 1.6)	Using Substitutes for Block Group Median Household Income		
		Tract Group Median Household Income	Block Group Median Family Income	Tract Group Median Family Income
	(1)	(2)	(3)	(4)
Predictor Variable (Standardized)				
Physical Activity (Wave I)	1.542* (.638)	1.527* (.600)	1.625** (.590)	1.639** (.612)
Covariates Included?	Yes	Yes	Yes	Yes
Constant	6.602*** (.265)	6.577*** (.267)	6.618*** (.272)	6.587*** (.270)
R^2	.121	.122	.122	.122
F-Statistic	11.217	10.952	14.680	1.758
Observations	16509	17042	15463	17032

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Appendix Table 1.7:
First Stage Regressions for 2SLS Model
Physical Activity (Wave I) Regressed on Instrumental Variables

	Standardized Physical Activity (Wave I)			
	(1)	(2)	(3)	(4)
Instrumental Variables				
Physical Activity Resources in a 3km network radius	.002***			
	(.000)			
Physical Activity Resources in a 3km Euclidean radius		.002***		
		(.000)		
Physical Activity Resources in a 3km weighted network radius			.004***	
			(.001)	
Physical Activity Resources in a 3km weighted Euclidean radius				.003***
				(.001)
log(Block Group Median Household Income)	.102***	.098***	.103***	.099***
	(.025)	(.025)	(.025)	(.025)
County Crime	-.010+	-.010+	-.010+	-.010+
	(.005)	(.005)	(.005)	(.005)
Local Government Direct Expenditure on Education per Capita	.000	.000	.000	.000
	(.000)	(.000)	(.000)	(.000)
Annual Rainfall	-.001	-.001	-.001	-.001
	(.001)	(.001)	(.001)	(.001)
Covariates Included?	Yes	Yes	Yes	Yes
Constant	.019	.019	.017	.018
	(.132)	(.133)	(.132)	(.133)
R^2	.118	.118	.118	.118
F-Statistic	11.217	10.211	11.684	10.753
Observations	19129	19129	19129	19129

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Appendix Table 1.8:
Years of Completed Schooling in Wave IV Regressed on Physical Activity (2SLS)

	Years of Completed Schooling			
	Preferred model (Column 5 of Table 1.6)	Alternative Specifications for 3km radius		
		Euclidean Radius	Weighted Network Radius	Weighted Euclidean Radius
	(1)	(2)	(3)	(4)
Predictor Variable (Standardized)				
Physical Activity	1.542^{*}	1.549^{*}	1.520^{*}	1.545^{*}
(Wave I)	(.638)	(.632)	(.637)	(.634)
Covariates Included?	Yes	Yes	Yes	Yes
Constant	6.602^{***}	6.602^{***}	6.601^{***}	6.602^{***}
	(.265)	(.265)	(.264)	(.265)
R^2	.121	.121	.121	.121
F-Statistic	11.217	10.211	11.684	10.753
Observations	16509	16509	16509	16509

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 1.9: First Stage Regressions for 2SLS Model Physical Activity (Wave I) Regressed on Instrumental Variables

	Standardized Physical Activity (Wave I)					
	(1)	(2)	(3)	(4)	(5)	(6)
Instrumental Variables						
Physical Activity Resources in a 1km network radius	.014***					
	(.003)					
Physical Activity Resources in a 5km network radius		.001***				
		(.000)				
Physical Activity Resources in a 8km network radius			.000***			
			(.000)			
Physical Activity Resources in a 3km weighted network radius				.004***		
				(.001)		
Physical Activity Resources in a 5km weighted network radius					.003***	
					(.000)	
Physical Activity Resources in a 8km weighted network radius						.002***
						(.000)
log(Block Group Median Household Income)	.103***	.099***	.094***	.103***	.100***	.097***
	(.024)	(.025)	(.025)	(.025)	(.025)	(.025)
County Crime	-.008	-.010*	-.010+	-.010+	-.010+	-.010+
	(.005)	(.005)	(.005)	(.005)	(.005)	(.005)
Local Government Direct Expenditure on Education per Capita	.000	.000	.000	.000	.000	.000
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
Annual Rainfall	-.001	-.001	-.001	-.001	-.001	-.001
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
Covariates Included?	Yes	Yes	Yes	Yes	Yes	Yes
Constant	.009	.020	.020	.017	.019	.020
	(.131)	(.132)	(.131)	(.132)	(.132)	(.131)
R^2	.118	.118	.117	.118	.118	.118
F-Statistic	10.078	9.617	8.169	11.684	10.603	9.386
Observations	19129	19129	19129	19129	19129	19129

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Appendix Table 1.10:
Years of Completed Schooling in Wave IV Regressed on Physical Activity (2SLS)

	Years of Completed Schooling						
	Preferred model (Column 5 of Table 1.6)	Alternative Radius Specifications					
		1km Network Radius	5km Network Radius	8km Network Radius	3km Weighted Network Radius	5km Weighted Network Radius	8km Weighted Network Radius
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Predictor Variable (Standardized)							
Physical Activity (Wave I)	1.542* (.638)	1.358* (0.659)	1.545* (0.646)	1.399* (0.683)	1.520* (0.637)	1.546* (0.640)	1.464* (0.663)
Covariates Included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	6.602*** (.265)	6.594*** (0.260)	6.602*** (0.266)	6.596*** (0.262)	6.601*** (0.264)	6.602*** (0.265)	6.599*** (0.263)
R^2	.121	.121	.121	.120	.121	.121	.121
F-Statistic	11.217	10.078	9.617	8.169	11.684	10.603	9.386
Observations	16509	16509	16509	16509	16509	16509	16509

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 1.11:
First Stage Regressions for 2SLS Model
Physical Activity (Wave I) Regressed on Instrumental Variables

	Standardized Physical Activity (Wave I)				
	(1)	(2)	(3)	(4)	(5)
Instrumental Variables					
Physical Activity Resources in a 3km network radius truncated at 99th percentile	.003*** (.000)	.003*** (.000)	.003*** (.000)	.003*** (.000)	.003*** (.000)
log(Block Group Median Household Income)		.120*** (.023)	.114*** (.024)	.111*** (.024)	.102*** (.025)
County Crime			-.012* (.005)	-.011* (.005)	-.010* (.005)
Local Government Direct Expenditure on Education per Capita				.000 (.000)	.000 (.000)
Annual Rainfall					-.001 (.001)
Covariates Included?	Yes	Yes	Yes	Yes	Yes
Constant	-.066 (.091)	-.061 (.095)	.002 (.094)	-.061 (.117)	.017 (.133)
R^2	.115	.117	.118	.118	118
F-Statistic	.408	26.343	15.951	10.633	11.246
Observations	19971	19129	19129	19129	19129

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Appendix Table 1.12:
Years of Completed Schooling in Wave IV Regressed on Physical Activity (2SLS)

	Years of Completed Schooling				
	With covariates only	Plus block group median household income	Plus county crime	Plus local government education expenditure per capita	Plus annual rainfall
	(1)	(2)	(3)	(4)	(5)
Predictor Variable (Standardized)					
Physical Activity	5.517	3.022***	2.153***	2.077***	1.580*
(Wave I)	(11.129)	(.766)	(.590)	(.603)	(.636)
Covariates Included?	Yes	Yes	Yes	Yes	Yes
Constant	14.121***	6.662***	6.627***	6.624***	6.603***
	(.116)	(.338)	(.288)	(.284)	(.266)
R^2	.000	.119	.120	.121	.121
F-Statistic	.408	26.343	15.951	10.633	11.246
Observations	17457	16509	16509	16509	16509

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Appendix Table 1.13:
First Stage Regressions for 2SLS Model
Physical Activity (Wave I) Regressed on Instrumental Variables

	Standardized Physical Activity (Wave I)				
	(1)	(2)	(3)	(4)	(5)
Instrumental Variables					
Physical Activity Resources in a 3km network radius truncated to 90th percentile	.005*** (.001)	.005*** (.001)	.005*** (.001)	.005*** (.001)	.005*** (.001)
log(Block Group Median Household Income)		.116*** (.023)	.109*** (.023)	.106*** (.023)	.100*** (.024)
County Crime			-.013** (.005)	-.012* (.005)	-.012* (.005)
Local Government Direct Expenditure on Education per Capita				.000 (.000)	.000 (.000)
Annual Rainfall					-.001 (.001)
Covariates Included?	Yes	Yes	Yes	Yes	Yes
Constant	-.087 (.091)	-.081 (.094)	-.013 (.093)	-.072 (.115)	-.021 (.135)
R^2	.116	.117	.118	.118	.118
F-Statistic	.381	22.259	14.027	9.544	10.184
Observations	19971	19129	19129	19129	19129

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Appendix Table 1.14:
Years of Completed Schooling in Wave IV Regressed on Physical Activity (2SLS)

	Years of Completed Schooling				
	With covariates only	Plus block group median household income	Plus county crime	Plus local government education expenditure per capita	Plus annual rainfall
	(1)	(2)	(3)	(4)	(5)
Predictor Variable (Standardized)					
Physical Activity (Wave I)	2.518 (8.118)	2.670^{***} (0.795)	1.774^{**} (0.611)	1.736^{**} (0.617)	1.403^{*} (0.641)
Covariates Included?	Yes	Yes	Yes	Yes	Yes
Constant	14.126^{***} (0.078)	6.648^{***} (0.317)	6.611^{***} (0.271)	6.610^{***} (0.270)	6.596^{***} (0.260)
R^2	.000	.119	.121	.121	.121
F-Statistic	.381	22.259	14.027	9.544	10.184
Observations	17457	16509	16509	16509	16509

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Appendix Table 1.15:
First Stage Regressions for 2SLS Model
Physical Activity (Wave I) Regressed on Instrumental Variables - Falsification

	Standardized Physical Activity (Wave I)				
	(1)	(2)	(3)	(4)	(5)
Instrumental Variables					
Physical Inactivity Resources in a 3km network radius	.013	.014^{+}	.016^{+}	.013	.012
	(.009)	(.008)	(.009)	(.009)	(.009)
log(Block Group Median Household Income)		.116***	.111***	.107***	.098***
		(.023)	(.024)	(.024)	(.025)
County Crime			-.009^{+}	-.008	-.008
			(.005)	(.005)	(.005)
Local Government Direct Expenditure on Education per Capita				.000	.000
				(.000)	(.000)
Annual Rainfall					-.001
					(.001)
Covariates Included?	Yes	Yes	Yes	Yes	Yes
Constant	-.046	-.043	.007	-.078	.006
	(.092)	(.097)	(.096)	(.120)	(.135)
R^2	.114	.115	.116	.116	.116
F-Statistic	0.466	13.834	8.600	6.376	6.791
Observations	19971	19129	19129	19129	19129

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 1.16:
Educational Attainment in Wave IV Regressed on Physical Activity (2SLS) - Falsification

	Years of Completed Schooling				
	With covariates only	Plus block group median household income	Plus county crime	Plus local government education expenditure per capita	Plus annual rainfall
	(1)	(2)	(3)	(4)	(5)
Predictor Variable (Standardized)					
Physical Activity	3.463	3.151***	2.056**	1.936**	1.191
(Wave I)	(5.613)	(.929)	(.741)	(.733)	(.774)
Covariates Included?	Yes	Yes	Yes	Yes	
Constant	14.124***	6.667***	6.623***	6.618***	6.588***
	(.090)	(.355)	(.290)	(.284)	(.261)
R^2	.000	.118	.118	.119	.119
F-Statistic	0.466	13.834	8.600	6.376	6.791
Observations	17457	16509	16509	16509	16509

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

CHAPTER 2:
Impact of Adolescent Physical Education Classes on Educational Attainment

Schools are an important setting in providing opportunities for young people to engage in physical activity (Bailey, 2006; Centers for Disease Control and Prevention, 2010; Wechsler et al., 2000). In particular, state and district policy changes in physical education (PE) class requirements are a potentially promising and relevant policy lever to increase adolescent physical activity. PE classes often represent the sole source of physical activity within the guidelines and framework of a state's curricular mandates for schools.

However, national and state policies to improve educational performance and attainment have focused primarily on factors affecting classroom instruction, such as mandating the use of standardized assessments (No Child Left Behind) and curricular reforms (Common Core State Standards Initiative, Every Student Succeeds Act) during the past few decades. As the focus on academic performance has increased, time allotted to physical activity opportunities in schools via recess and physical education have been reduced to promote more instruction time for subjects such as mathematics and language arts that are tested in these standardized assessments (Centers for Disease Control and Prevention, 2010; Institute of Medicine, 2013).

Over the past decade, PE participation has decreased. The percentage of high school students who attended PE classes daily decreased from 42% in 1991 to 25% in 1995 and has remained at roughly that level until 2013 (29%). In 2013, 42% of 9th-grade students, but only 20% of 12th-grade students, attended PE class daily (Kann et al., 2014). These percentages do not come close to the guidelines regarding daily physical activity provided by the US Health and Human Services Department, which recommends one or more hours of physical activity each day (Institute of Medicine, 2013).

Additionally, participation in PE is widely inconsistent across the US. In 2013, the prevalence of ever having attending PE classes ranged from 31% to 93% across 37 states[3]; across 19 large urban school districts, the prevalence ranged from 28% to 85%[4]. Students also appear to participate less in PE as they age—the prevalence of attending PE classes was higher amongst 9th-grade students(64%) than 10th-grade (51%), 11th-grade (40%), and 12th-grade (35%) students (Kann et al., 2014).

As most US adolescents spend the majority of their waking hours in schools, this decrease in physical activity may have adverse impacts not only on youth health but may also have adverse impacts on educational performance and attainment. Administrators and policymakers may continue to decrease required PE in lieu of more curricular classes in school if there are no educational benefits of PE, even at the risk of increasing the chances of youth health problems such as obesity. While prior research has focused on the effects of physical activity on educational achievement outcomes in children, there are no studies focused specifically on the causal impacts of PE on educational attainment, especially in adolescence.

Given the lack of research on the impacts of PE on educational attainment, a close substitute would be to examine the impact of PE on educational performance. In a review of studies examining the influence of sports, PE, or physical activity upon academic performance between 1966 and 2007, Trudeau and Shephard (2008) identified only seven experimental studies that use PE interventions to make causal inferences. The authors found programs that increased weekly PE time led to a substantial reduction in time allocated for other subjects but

[3] Excluded states include California, Colorado, Connecticut, Indiana, Iowa, Minnesota, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, and Washington

[4] Large urban school districts include: Baltimore, MD; Boston, MA; Broward County, FL; Charlotte-Mecklenburg, NC; Chicago, IL; Detroit, MI; District of Columbia; Duval County, FL; Houston, TX; Los Angeles, CA; Memphis, TN; Miami-Dade County, FL; Milwaukee, WI; New York City, NY; Orange County, FL; Palm Beach County, FL; Philadelphia, PA; San Bernardino, CA; San Diego, CA; San Francisco, CA; Seattle, WA.

found either no change or a slight improvement in child academic outcomes and argued that the efficiency of learning was enhanced.

The largest and most comprehensive of these interventions examines the effects of a 2-year health-related PE program on standardized academic achievement scores. Sallis et al. (1999) theorized that enhanced PE, determined by increased time in PE and professional physical educators, would have positive impacts on academic performance. Seven Southern California public elementary schools in a single school district were stratified by the percentage of ethnic minorities and randomly assigned into one of three conditions: 1) specialist condition, where a group of certified PE specialists implemented the Sports, Play, and Active Recreation for Kids (SPARK) program for 80 minutes per week of PE, 2) trained teacher condition, where classroom teachers were trained by research staff to implement the SPARK program for 65 minutes per week of PE, and 3) control condition, where the usual PE program was implemented for 38 minutes per week of PE. There were no significant differences between the groups on the mathematics assessment of the Metropolitan Achievement Test. However, while the specialist condition was superior to the control on the reading assessment, they were inferior on the language assessment. Collectively, Sallis et al. (1999) argued that was no significant difference in academic outcomes across the groups despite the two enhanced PE groups spending more minutes per week to PE than the control group.

However, this and most of the other experimental and quasi-experimental studies use samples of children up to grade 6 and not adolescents. Furthermore, the small sample sizes of these interventions question the generalizability of these results over a nationally representative population. Most importantly, the long-term impacts of these interventions, such as years of completed schooling and college enrollment, were not explored.

When considering quasi-experimental studies using nationally representative samples focused around the causal impact of PE, the extant literature typically examined physical health as the sole outcome of interest. Cawley et al. (2007) used an instrumental variables approach using state minimum PE requirements from the 2001 Shape of the Nation report to estimate the effect of additional minutes per week spent physically active in PE class on three measures of physical activity (vigorous exercise, light activity, strength-building activity) and weight (body mass index, at risk of overweight, overweight) for a nationally representative sample of adolescents between 15 and 18. They found active PE time raises the number of days per week girls report having exercised vigorously or having engaged in strength-building activity. However, they did not find that additional active PE time impacts physical activity or weight for boys.

Similarly, Cawley et al. (2013) also used state-mandated required number of minutes of PE per week as an instrumental variable to find the causal effect of PE on youth obesity for 5th graders. They found additional minutes of PE per week lowers BMI z-score and reduced the probability of obesity among 5th graders. However, both of these studies focused on the causal impact of PE on health related outcomes and failed to consider neither educational achievement nor attainment as a potential outcome.

Other studies have attempted to estimate the causal impact of PE on education using grants to improve school PE or other forms of school-based physical activity. In one particular case, the state of Texas granted $37 million to improve PE in high-poverty middle schools from the 2007-08 to the 2010-11 school year. Using a FitnessGram assessment required by all middle schools in Texas to measure strength and flexibility and the percentage of kids who scored at the "proficient" or "commended" level by grade and gender within each school in the Texas

Assessment of Knowledge and Skills (TAKS) assessment to measure academic performance, von Hippel and Bradbury (2015) used a longitudinal fixed-effects model to find that these grants improved student strength and flexibility as measured by the FitnessGram but it did not lower BMI or raise academic achievement. However, these grants that are funded by foundations and the government are voluntary and do not require changes in mandates for required PE attendance. Furthermore, an analysis of the allocation of these grants found that most of these funds were spent on sports and fitness equipment and there were no reports of these grants having any impacts on increasing the amount of PE.

Although the returns of PE to physical health are well-established in the literature, the impact of PE on educational attainment is an interesting and understudied avenue for future research, especially for adolescents. Findings from this chapter can provide insight on potential political levers, such as state, district, and school mandates to increase PE requirements in schools, as a way to improve educational attainment.

Data

The data are drawn from the National Longitudinal Study of Adolescent Health (Add Health), a prospective longitudinal study of a nationally representative sample of adolescents in grades 7 through 12 in the US during the 1994-1995 school year who were followed until 2007-2008. The Add Health dataset contains multiple rounds of surveys from different sources, including in-home surveys of adolescents and their parents, in-school surveys of adolescents administered the in-home surveys and their peers, transcript information, and contextual information of the adolescent's school, including but not limited to, type of school, number of teachers, and average classroom size.

Adolescents were interviewed four times with a series of in-home interviews conducted in 1994-1995 (Wave I), 1996 (Wave II), 2001-02 (Wave III), and 2007-08 (Wave IV) when they were between ages 24-32. The students who attended the same schools as those in the in-home interview (more than 90,000 adolescents) between grades 7 through 12 were also administered an in-school questionnaire in a 45- to 60-minute class period between September 1994 and April 1995 in Wave I. This chapter draws data regarding PE from the Wave I in-home survey to predict educational attainment from the Wave IV survey. Covariates from the in-home and in-school questionnaire from Wave I were used to reduce bias in the relationship between PE and educational attainment.

This study uses of a subset of 6,095 adolescents who reported a non-missing value of the intensity of their PE during the in-home interview in Wave I as well as their educational attainment between ages 24-32 in Wave IV. Due to the study design of the Add Health, analysis include standard errors that are clustered by the principal sampling unit—a school identifier based on the school attended by the adolescents in Wave I—following the recommended guidelines for using the Add Health dataset. Table 2.1 provides full sample descriptive information for the main predictor variable and outcomes of interest and Table 2.2 provides descriptive information for the full sample for the covariates in the analysis.

Analytic Strategy

The estimated ordinary least squares (OLS) model typically used is:

$$Outcome_i = \beta_0 + \beta_1(PE\ Time)_i + \delta' X_i + \varepsilon_i \qquad (1)$$

where $Outcome_i$ reflects the educational attainment outcomes for adolescent i. PE $Time_i$ corresponds to hours per week spent exercising or playing sports in PE class, and X_i captures the vector of demographic, family, and individual characteristics covariates. ε_i is the error term.

However, it would be unrealistic to assume that an OLS regression of educational attainment on PE time would produce a consistent estimate of the impact of PE on these outcomes. In some schools, PE classes are electives and students with a preference for exercise may be more likely to enroll in optional PE classes. This selection may generate a correlation between PE time and educational attainment even if PE time does not have a causal impact on educational attainment. Another potential issue would be a student's misreporting of PE time. If PE time is reported with error, the effect of PE time on educational attainment would be understated as this misreport may also generate a correlation between PE time and the outcomes of interest. Lastly, the extent to which schools offer PE classes in lieu of college preparatory classes or remediation classes may be based on school characteristics or requirements, which would lead to omitted variable bias in an OLS regression based on observable characteristics.

To account for the presence of these selection and misreporting issues, instrumental variables (IV) are used in a two-stage-least squares (2SLS) model to generate a consistent estimate of the impact of additional PE time on educational attainment. The IV method addresses this problem by studying variation in PE time that is beyond the students' control. The use of IVs also eliminates the influence of any measurement error in student reports of PE time. Given the wealth of information provided in the Add Health data set, school PE time requirements can be used to obtain an unbiased predictor for PE time and understand the causal impact of PE time on educational attainment.

School level PE requirements may impact the intensity of PE participation of the adolescent that is outside his or her control. If a school requires students to participate in PE, students who would typically not have participated in PE would have to participate in order to graduate. Furthermore, schools that require greater levels of participation relative to other schools would presumably have students that participate in more PE than students in other schools. These school requirements should have an impact on student enrollment in PE but should not have a strong correlation with a student's educational attainment.

However, school level factors such as PE requirements may not prove to be a good instrument for PE participation by themselves and it is important to control for additional characteristics that can impact PE time that is outside of the adolescent's control. In addition to the surveys of adolescents, the Add Health also surveys school administrators in the schools attended by the adolescents in Wave I and provides information regarding the adolescent's school, as well as the demographic features of schools and school districts from the Office for Civil Rights and the US Census. By controlling for school factors and contextual environment characteristics surrounding the school, a more precise unbiased predicted value of PE can be obtained.

Among other school factors, private schools may be more likely to have reduced PE requirements relative to their public school counterparts as a means to increase curricular time in academic subjects, such as mathematics and science. Private schools may also not have a PE requirement for graduation whereas public schools may require PE due to district and state mandates.

Additional factors that may influence the amount of required PE include school size and resources. Larger schools may be more likely to have increased PE requirements than smaller schools as they are likely to have more faculty to teach PE. Smaller schools may be more likely to not have enough staff to employ a full time PE instructor, resulting in a decrease in the amount of PE required to graduate from high school. Additionally, schools with more funding are more likely to have the resources to hire more faculty and afford the materials or equipment that a school may need to properly hold a PE class relative to schools with limited funding.

It is also important to account for different selection factors that parents use to determine where they (and their children) live. Among others, selecting into a certain neighborhood can be a function of wealth or socioeconomic status—houses in the same neighborhood often share similar prices and costs of living. Families above a certain income threshold may elect to choose a certain schooling district due to both their academics and their requirements for graduation, which may include PE.

Other important neighborhood selection factors include crime and climate. Parents may also select to live in areas with less crime. Schools in areas with high crime rates may elect to reduce the amount of required PE as the outdoor areas (i.e. track and field) where students would participate in PE would not be safe and put students at risk. Similarly, parents may choose to live in areas with increased rainfall. Schools in these areas may also elect to reduce the amount of required PE as the outdoor areas (i.e. track and field) where students would participate in PE may not be accessible for PE classes.

In sum, school PE requirements will be used as an instrument to predict the amount of PE participation while controlling for school level characteristics such as school type, size, and resources as well as some parental neighborhood selection factors.

The estimated model requires a two-stage least squares (2SLS) model. The first equation runs an OLS regression of PE time on the instruments to get a predicted value for PE Time:

$$\widehat{PE\ Time}_i = \gamma_0 + \gamma_1 Z_i + \vartheta' Y_i + v_i \qquad (2)$$

where $\widehat{PE\ Time}_i$ is the predicted value for hours per week in PE classes for adolescent i, and Z_1 is the instrumental variable. Y_i comprises a vector of covariates from the adolescent's school and neighborhood, and v_i is the error term. By forming predictions for PE time to be used in the second stage, I can correct for the correlation between the error term and independent variables. The fitted value of $\widehat{PE\ Time}_i$ would then be inserted into the original OLS equation from equation (1):

$$Outcome_i = \beta_0 + \beta_1 \widehat{PE\ Time}_i + \delta' X_i + \epsilon_i \qquad (3)$$

ϵ_i is a composite error term that is uncorrelated with the predicted value of PE time and X_i is the vector of demographic, individual, and family control covariates. The results from this 2SLS model allows for the causal impact of PE on years of completed schooling and other attainment measures.

Measures

Total PE Time

During the in-home interview in Wave I, adolescents were asked on how many days they go to PE classes at school in an average week if they were in school. Answers ranged from zero to 5 days. If they reported the number of times they went to PE classes, they were asked how many minutes they spent actually exercising or playing sports during an average PE class at school (less than 10 minutes, 10 to 20 minutes, 21-30 minutes, or more than 30 minutes). The midpoints of each of these categories were multiplied by the average number of days per week they attend a PE class to create a composite variable for total PE time. For the category with more than 30 minutes, 35 minutes was used to maintain a linear pattern with the other categories. The range for total PE time was from zero to 2.92 hours per week, with a mean of 1.22 hours (Table 2.1)

Educational Attainment

Educational attainment is a heterogeneous process, with the determinants of success in completing high school likely to differ from the determinants of entry into and completion of college or other post-secondary schooling. Separate models for measures of years of completed schooling, high school graduation, college entry, and graduating college between ages 24-32 in Wave IV of the data were estimated. If years of completed schooling were not available between ages 24-32, attainment from when respondents were between ages 18-26 from Wave III was used.

Years of completed schooling is a continuous measure while high school graduation, college entry, and graduating college are dichotomous. The rate of high school completion averaged 86%, college attendance averaged 73%, and college graduation averages 28% (Table 2.1). Cases where subjects reported a GED as high school completion, the years of completed schooling was adjusted to reflect 11 years of completed schooling instead of 12.

Covariates

In order to reduce potential bias between PE and education, observable adolescent demographic, family, school, and individual covariates in the Add Health data were included in the analysis. An important strength of the Add Health is the depth and breadth of information collected in the parent interview taken from in-school surveys of the adolescents and in-home surveys of the adolescents and their parents. The selection of control variables was driven by the goal of selecting measures that might be confounded with PE but not a part of the causal mechanism by which PE might affect educational attainment. A full list of these control measures and their summary statistics is provided in Table 2.2.

Adolescent and maternal background characteristics taken from in-school surveys of the adolescents and in-home surveys of the adolescents that are used as covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status, mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, and if English is spoken at home. Additionally, parents reported their total family income in 1994, and indicated if they were able to pay their bills. They also reported if they received any form of welfare (Social Security or Railroad Retirement, Supplemental Security Income, Aid to Families with Dependent Children, food stamps, unemployment or worker's compensations, or a housing subsidy or public housing). The weight statuses of both parents are also included as covariates.

To reduce bias in the association between PE and educational attainment caused by health status, self-reports of height and weight were used to determine the weight status (healthy/normal, overweight, obese) of each adolescent in Wave I. If the adolescent was 20 years old or older at the time of the interview, BMI was calculated and weight status was determined using normal BMI cutoff-points were used. If the adolescent was younger than 20 years old in Wave I, percentile BMI was calculated by gender and age in months using guidelines provided by the Center for Disease Control.

To best account for educational performance before the start of the study, self-reports of GPA (English, math, humanities, science) from the in-school questionnaire were used as a proxy for prior educational performance. Additional covariates include if in-home survey was conducted during summer months, and grade fixed effects to account for the chance that adolescents further along in high school (e.g. 12^{th} graders) are more likely to graduate than those in younger cohorts (e.g. 9^{th} graders).

Variables used for 2SLS model

Average PE in School.

Examining school requirements for PE can provide a means to study variation in PE time that is beyond the students' control. Although there is no question on the school administrator survey that explicitly reports these requirements, it is possible to find a proxy for this requirement by taking the average PE time by school reported by all responding adolescents attending that school.

Given the study design of the Add Health, roughly 20% of all adolescents administered the in-school survey were selected to be part of the core sample who were administered the in-home administration. For each respondent in the in-home survey who reported the amount of weekly PE participation, the average of all respondents in the sample at the same school discounting the focal respondent was taken. This average would not be biased by the respondent and provides a proxy for school requirements for PE. These requirements would predict intensity of participation in PE but should not have an impact on child educational outcomes, especially because these requirements would be consistent across all adolescents in the same school. Summary statistics for average school PE time is presented in Table 2.1.

School characteristics.

In order to account for school level characteristics that may bias the relationship between average weekly PE in the school and the amount of weekly PE that a student participates in, school type, school size, and school resources were considered as control variables in the first stage of the 2SLS model. School type (i.e. public or private) and measures of school size (e.g., total number of teachers in the school and the average number of students per class) were taken from the school administrator questionnaire that reported school level characteristics for each school in the study. Additionally, the number of students on a school's roster was provided by the Office for Civil Rights.

The amount per capita of direct expenditure on education by the local government was also included as a measure of school resources. Expenditure data is derived from the State and

Metropolitan Area Data Book and the County and City Data Book, which are provided by the U.S. Bureau of the Census. Direct education expenditure is the provision or support of schools and other educational facilities and services. These services include transportation, school milk and lunch programs and other cafeterias, as well as health and recreational programs. Summary statistics for school characteristics used in the first stage of the 2SLS model are presented in Table 2.1.

Neighborhood characteristics.

In order to account for parental neighborhood level selection characteristics that may bias the relationship between average weekly PE in the school and the amount of weekly PE that a student participates in, proxy variables for neighborhood wealth or socioeconomic status, crime rates, and climate were considered as control variables in the first stage of the 2SLS model.

The median household income of all families within a census block group was used as an indicator for a neighborhood's socioeconomic status. The data regarding household income is derived from the Census of Population and Housing, 1990: Summary Tape File 3A (STF 3A), which contains data on population and housing characteristics produced from the 1990 Decennial Census, including education. These variables are derived from the 1990 Census long-form questionnaire that approximately 1 in 6 of all housing units in the U.S. received. Thus, data in the STF 3A are sample data that have been weighted by the Census Bureau to represent the total population of the geographic units to which they pertain. To account for potential outliers, the average income in a block group was log transformed.

The total number of crimes per 100,000 people in an adolescent's county of residence were used as an indicator of the community environment. Although the total number of crimes in a census block group would have been ideal, total number of crimes per 100,000 people in a county is the smallest aggregate measure of crime available in the Add Health data. Crime data are based primarily on the 1995 Uniform Crime Reporting data, obtained from the National Archive of Criminal Justice Data. In certain instances, data from 1990 through 1994 were used, when a county associated with an Add Health respondent lacked 1995 crime statistics.

The total annual rainfall was included as a proxy measure for climate. Rainfall data for each Wave I respondent was based on data from the adolescent's nearest climate station during Wave I. If the climate station nearest to the respondent had no data on the amount of rainfall, the adolescent was assigned a value of rainfall for the next nearest station with available data. The total amount of rainfall over the course of the year was collected for each adolescent.

Summary statistics for all neighborhood variables used in the first stage of the 2SLS model are presented in Table 2.1.

Results

Descriptive Statistics

Table 2.1 and 2.2 provides descriptive statistics for the main predictors, outcomes, and covariates used the analyses. On average, the respondents reported that they participated in PE 1.2 hours week (standard deviation = 1.20) and by Wave IV, respondents averaged 14.11 years of schooling (standard deviation 2.17). The sample was 50% female, and in terms of race/ethnicity, the sample was 29% white, 25% black, 23% Hispanic, 9% Asian, and 14% Other. Mothers reported, on average, 13.00 years of schooling (standard deviation = 2.74). 15% of the sample was overweight while 11% of the sample was obese.

Table 2.3 shows the correlations between the main predictor and outcomes. PE in Wave I is negatively associated with years of completed schooling and graduating high school but not associated with attending college or graduating college. However, the magnitudes for each of these correlations are less than 0.10.

OLS Regression Results

The associations between PE time and years of completed schooling between ages 24-32 were first examined in Table 2.4. The first column of Table 2.4 shows estimates from a bivariate regression model between PE and years of schooling, without any other predictors. In the absence of any controls, an hour increase in PE in Wave I is not significantly associated with years of completed schooling.

The second model shows estimates from an OLS regression model with a full set of controls. In the presence of the host of child, family, and other demographic controls, PE is still not significantly related to years of completed schooling. Complete regression results are presented in Appendix Table 2.1.

Estimates from logistic regression models predicting high school graduation, attending college, and graduating from college are also presented in Table 2.4 using marginal probability coefficients. Bivariate regression models and OLS models with the full set of controls are reported for each of the three logistic outcomes. When accounting for the full set of controls, PE is not significantly associated with graduating high school, attending college, or graduating college. Results are also presented in odds ratios in Appendix Table 2.2.

2SLS Regression Results

Table 2.5 presents results from the first stage of the 2SLS analytic model in which the average school PE is used as an instrumental variable to predict weekly hours of PE, conditioning on school type, size (i.e., number of teachers, average students per class, number of students on the school's roster), and resources (i.e., local government direct expenditure per capita on education) as well as parental neighborhood selection factors (i.e. block group median household income, county crime, and annual rainfall). In order for the average school PE to be considered a good instrument, one of the main criteria is for average school PE to be significantly associated with hours of PE. Column 1 of Table 2.5 shows that an additional hour of average school PE is associated with a 0.791 hour increase of weekly PE, conditioning on school type, size, and resources and parental neighborhood selection factors.

A potential concern to the first stage estimates is that the relationship between school average PE and hourly PE is biased by schools in which there are less than 10 adolescents who reported their weekly PE. In other words, these schools may not provide a stable estimate for average school PE. Column 2 of Table 2.5 shows the same analytic model as that in Column 1 while dropping those adolescents that attend schools with less than 10 reports of PE per school. This subset of adolescents finds practically identical first stage estimates to Column 1—an additional hour of average school PE is also associated with a 0.791 hour increase of weekly PE, conditioning on school type, size, and resources, as well as parental neighborhood selection factors such as block group median household income, county crime, and annual rainfall.

Another criterion for an instrumental variable to be considered a good instrument is for the F-statistic in the reduced form of the 2SLS model to be larger than 10 to ensure that the maximum bias in the instrumental variable estimators should be less than 10%. Column 1 of Table 2.5 shows that in the F-statistic is 77.80. When considering the subset of adolescents who attend schools where more than 10 students reported their hourly PE, the F-statistic remained fairly consistent at 76.92 (Column 2). Each of these models exhibits F-statistics greater than the cutoff point of 10 that would consider average school PE to be a weak instrument.

Table 2.6 presents 2SLS model results in which a predicted value for hourly PE estimated from the first stage equation in Table 2.5 was used to estimate the impact of weekly hours of PE on years of completed schooling. Column 1 of Table 2.6 presents results from the 2SLS model using the predicted value of hourly PE from Column 1 of Table 2.5 with the full set of covariates from the OLS model. An additional hour of weekly PE predicts an increase in years of completed schooling by .304 years. Column 2 replicates the model from Column 1 with the subset of students who attended schools in which more than 10 students reported their average weekly PE participation. The results are slightly larger in which an additional hour of weekly PE predicts an increase in years of completed schooling by .312 years.

Table 2.7 presents 2SLS model results in which a predicted value for hourly PE estimated from the first stage equation in Table 2.5 was used to estimate the impact of weekly hours of PE on discrete measures of educational attainment such as graduating high school or college. Although the outcomes are discrete, the results use an OLS in the second stage of the 2SLS to present linear probabilities. Columns 1, 3, and 4 in Table 2.7 present results from the 2SLS model using the predicted value of hourly PE (from Column 1 of Table 2.5) and the full set of covariates in the OLS model to estimate the impact of an additional hour of weekly PE on high school graduation, attending college, and graduating college, respectively. An additional hour of weekly PE increases the probability of graduating high school and attending college by 4.4 and 4.6%, respectively. When restricting the sample to the subset of students who attended schools in which more than 10 students reported their average weekly PE participation, the estimates are practically identical (Table 2.7 Columns 2, 4, and 6).

Robustness Checks

A potential threat to the general conclusion are heterogeneous associations by race, gender, income, and health. To test for potential differential associations, interaction terms between PE and race, grade at Wave I, gender, income, and weight status were included to the preferred OLS model in Table 2.4 examining years of completed schooling (Appendix Table 2.1). Columns 3-7 of Appendix Table 2.1 shows that the associations between PE and years of completed schooling do not vary by gender, grade at Wave I, race, total family income, or weight status.

It would also help the general conclusion of the study if additional instrumental variables could be used to replicate and confirm the results of this study. One potential instrument that could be used to establish a causal estimate for the impact of PE on educational outcomes is the availability of athletic/physical services or a recreation center. The availability of these resources can impact how many PE classes students choose to take. For example, if a junior high or high school lacks the proper services and facilities to house a PE class, it is possible that PE is not offered. In elementary schools, poor facility provisions have been linked to less PE time (Fernandes & Sturm, 2010). These facilities can have an impact on student enrollment in PE but should not have a strong correlation with a student's educational attainment.

The school administrator questionnaire in the Add Health data provides information regarding availability of athletic/physical services and of a recreation center in a school. School administrators reported if athletic/physical services and a recreation center are provided on school premises, provided by the district at another school, are referred to other providers, or neither provided or referred. Two different specifications of the availability athletic/physical services variable could be used as an instrumental variable: 1) athletic/physical services are provided on school premises and 2) athletic/physical services are provided on school premises or provided by the district at another school. The availability of a recreation center at the school could also be used as an instrumental variable. There was no difference between the recreation center being provided on school premises or provided by the district at another school.

Of the schools that report the provision of athletic/physical services, 41% of the adolescents attended schools with athletic/physical services are provided on school premises and 47% of the adolescents attended schools with athletic/physical services are provided on school premises or provided by the district at another school. A recreation center on school premises was available for 31% of adolescents (Appendix Table 2.3). Bivariate correlations between these potential additional instrumental variables and weekly PE showed null to positive associations but none of the statistically significant correlations being greater than .10 (Appendix Table 2.4).

Appendix Table 2.5 uses these variables to predict hours of PE in the first stage of the 2SLS model. Athletic/physical services at an adolescent's school (Column 1) or having a recreation center available at an adolescent's school (Column 3) were not significantly associated with PE when considering the same conditions in the first stage equations as the 2SLS models with average school PE, making it a poor instrumental variable. Additionally, the F-statistics for the models using these instruments were less than the accepted cut-off value of 10. Having athletic/physical services provided by the district at an adolescent's school or at a nearby school was significantly associated with PE participation. However, the F-statistics for this model indicates that this variable is a poor instrument as the F-statistic is less than 10 (Column 2).

Another potential instrument to explore are state PE mandates following the work of Cawley et al. (2007) and Cawley et al. (2013). Data regarding state PE mandates from first wave of the School Health Policies and Practices Study (SHPPS) in 1994 was merged to the first wave of the Add Health data. State laws can impact how many PE classes students choose to take. Similarly, if there are no state-mandated minimal PE requirements, the school does not have an incentive to offer PE. The availability of and state mandates regarding PE in a given school can predict if a student enrolls in PE but should not have a strong correlation with a student's educational attainment. In the analysis sample, 62% of the adolescents live in states with mandatory PE (Appendix Table 2.3).

Bivariate correlations between these state PE mandates and weekly PE showed a small statistically significant association of -0.03 (Appendix Table 2.4). However, state mandates are not predictive of intensity of PE participation with the inclusion of the school and neighborhood conditions in the preferred 2SLS model and as such, does not a present statistically significant first stage that can help produce the causal implications of PE on academic attainment (Appendix Table 2.5 Column 4). The lack of a relationship between state policies and PE may be considered unsurprising as few schools provide daily PE even though most states and districts had adopted a policy stating that schools will teach PE using data from the 2006 wave of the School Health Policies and Programs study (Lee, Burgeson, Fulton, & Spain, 2007). State mandates are confirmed to be poor instruments as due to F-statistics being less than 10 (Appendix Table 2.5). Cawley et al. (2013) and Cawley et al. (2007) find state mandates to a good instrument for elementary and middle school children, respectively, but state mandates may not be a good instrument to predict high school PE participation for high school students.

2SLS results using predicted values of weekly PE to predict years of completed schooling using these bad instruments show imprecise and statistically insignificant relations (Appendix Table 2.6). Although the results may have been confirmed through additional and alternative instrumental variables, school level resources and state PE policies are not statistically related to the amount of PE that an adolescent attends. However, these robustness checks can help inform policy makers of some of the unsuccessful ways to improve the amount of weekly PE.

Discussion

The results demonstrate the importance of PE on educational attainment. In fact, it appears that adolescents benefit academically from increased time in their PE classes. The instrumental variable approach helps account for potential unobservable factors would bias the relationship between PE and educational attainment in a traditional OLS model, such as misreporting of and selection into PE. This causal estimate of PE on educational attainment presents a basis for future research and potential policy changes.

However, it is important to contextualize for whom the effects are relevant. Although instrumental variables can be used to estimate an unbiased or causal estimate of PE on educational attainment, this estimate is not relevant across all adolescents. When considering the impact of an additional hour of PE as a potential policy lever to improve educational attainment, there will be a number of students for whom this policy lever would be irrelevant. For example, the adolescents who enjoy PE classes would likely already be signed up for PE classes and would not be affected by this potential policy lever.

When considering the population for which a potential policy lever to increase PE time would be relevant, individuals will fall into one of four potential groups: 1) “always-takers” or students who would take PE classes regardless of any changes of policy; 2) “never-takers” or students who would find a way to not participate in PE classes regardless of any policy mandates; 3) “compliers” or students who would only take PE classes if they were mandated to do so via policy and would not take PE classes if they were not required to do so; or 4) “defiers” or students who would not participate in PE classes if they were required to via policy and would take PE classes if they were not required to do so. The unbiased estimate obtained using instrumental variables is considered the "local average treatment effect" and this estimate is only applicable for "compliers," or individuals whose behaviors would change as a function of potential changes in educational policy. It is possible that the total number of adolescent compliers in this quasi-experiment make up a small proportion of the population as there are no current means of identifying compliers. Future research should seek to identify and understand who the compliers in this analysis are.

Additionally, it is important to note the size of the standard error of .153, which gives fairly large 95% confidence interval of .05 years to .65 years. Given these estimates and large confidence interval, a randomized control trial that increase PE time is likely to have a positive impact on educational attainment. However, the true effect of an additional hour per week of adolescent PE in a randomized control trial may lie anywhere between the range of .05 and .65 years.

The relatively large standard deviation of years of completed schooling in Table 2.1 is also an important consideration. Converting this unstandardized coefficient to a standardized variable changes the converts the coefficient of .304 years into an effect size of .17 standard deviations. It is useful to compare this effect size with the effect sizes in studies focused around physical activity and educational achievement due to the lack of experimental studies that use educational attainment as an outcome. In a meta-analysis of 59 studies focused around physical activity and education in children from 1947 to 2009, Fedewa and Ahn (2011) find a standard deviation increase physical activity to be associated with a .35 standard deviation increase in academic achievement in the experimental or quasi-experimental studies in the meta-analysis. However, in studies with physical activity interventions that occurred once a week, Fedewa and Ahn (2011) report the average effect size to be .16 standard deviations. In physical activity interventions that occurred twice a week, the average effect size was reported as .27 standard deviations.

Given the benefits of adolescent PE on educational attainment, policy-based initiatives to increase PE in junior high and high school may have significant impacts on educational attainment. One potential policy lever to increase PE is to increase the amount of required PE credits for high school graduation. This may be one of the easier means to increase PE as many states already include PE as part of the high school graduation requirement.

Furthermore, PE participation has also decreased over the past decade. The percentage of high school students who attended daily PE classes decreased from 42% in 1991 to 25% in 1995 and has remained at roughly that level until 2013 (29%) (Kann et al., 2014). Increasing required PE class mandates would not be a radical proposition as schools and students have previously been able to accommodate increased physical activity as part of their school curriculum in prior years. Policy makers should consider increases in weekly adolescent PE as a means to improve educational attainment outcomes, above and beyond the potential health benefits of PE.

In sum, adolescent PE classes are a significant predictor of later academic achievement for certain students. As the focus on academic performance in schools has increased, time allotted to PE classes in schools have been reduced to promote more instruction time for subjects such as mathematics and language arts, at the expense of other subjects such as PE classes (Centers for Disease Control and Prevention, 2010; Institute of Medicine, 2013), which may have adverse impacts of educational achievement. Sacrificing PE classes for additional time for mathematics and language arts may mitigate some of the benefits of additional instructional time. Quasi-experimental estimates using instrumental variables show significant and substantial impacts of PE classes on educational achievement and future work should both replicate and extend the findings of this paper.

Table 2.1
Summary Statistics: Main Predictor and Outcome Variables

	Mean/%	Std. Dev	Min	Max
Predictor Variables (Wave I)				
Weekly Physical Education Time (Hours)	1.22	1.20	.00	2.92
Outcome Variables				
Wave IV Attainment				
Highest Grade Completed	14.11	2.17	7.00	22.00
Graduate High School	86.03%			
Attend College	73.07%			
Graduate College	28.39%			
Instrumental Variables				
Weekly Average PE in school (hours)	1.22	.50	.23	2.86
Weekly Average PE in school (hours) with at least 10 adolescents per school	1.22	.50	.26	2.86
Instrumental Variable Conditions				
School Type				
Public	93.27%			
Private	6.73%			
School Size				
Number of Teachers	67.20	34.65	5.00	182.00
Average Class Size	26.95	6.30	10.00	39.00
Number of Students on Roster (100)	12.55	8.82	.26	35.46
Local Government Direct Expenditure per Capita ($100)	6.75	1.40	.03	11.38
log[Block Group Median Total Family Income($10000)]	1.02	.49	-.69	2.70
County Crime	5.89	2.80	.57	13.72
Annual Rainfall	37.30	15.24	3.11	91.00

Table 2.2
Summary Statistics: Covariates

	Mean/%	Std. Dev	Min	Max
Female	49.50%			
Race/Ethnicity				
Hispanic	23.14%			
Black	24.52%			
Asian	8.99%			
Other	14.49%			
US born	88.39%			
Parents US born	78.91%			
Live with both parents	69.88%			
English spoken at home	85.84%			
Mother's Education	13.00	2.74	.00	20.00
Mother's age at birth	25.16	5.43	13.00	48.00
Birth weight (lb)	7.22	1.40	3.00	12.00
Parents' Marital Status				
Married	70.24%			
Single/Never Married/Widowed/Separated	15.74%			
Divorced	14.02%			
log(total family income in1994)	3.49	0.81	0.00	6.91
Total family income (1994)	44.10	51.47	0.00	999.00
Can't pay bills	19.37%			
Welfare recipient	30.78%			
Mother is Obese	17.63%			
Father is Obese	9.66%			
Weight Status				
Normal/Healthy	74.42%			
Overweight	14.63%			
Obese	10.95%			
Self-reports of GPA at beginning of school year				
English	2.80	.97	1.00	4.00
Math	2.69	1.04	1.00	4.00
Humanities	2.85	1.01	1.00	4.00
Science	2.82	1.01	1.00	4.00
Grade in Wave I				
7th	13.24%			
8th	12.90%			
9th	17.45%			
10th	20.80%			
11th	19.69%			
12th	15.92%			

Table 2.3
Correlation Matrix Between Main Predictor and Outcome Variables

	(1)	(2)	(3)	(4)	(5)
Educational Attainment (Wave IV)					
Years of completed schooling	1.00				
Graduate high school	.43***	1.00			
Attend college	.71***	.39***	1.00		
Graduate college	.80***	.23***	.38***	1.00	
Physical Education Time (Hours per week)	-.03*	-.03*	-.00	-.01	1.00

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 2.4
Educational Attainment in Wave IV Regressed on Physical Education (OLS)

	Highest Grade Completed		Graduate High School[&]		Attend College[&]		Graduate College [&]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Predictor Variable (Standardized)								
Weekly Physical	-.059	.014	-.007	.005	-.001	.009^{+}	-.004	.006
Education (Hours)	(.042)	(.032)	(.005)	(.004)	(.007)	(.005)	(.008)	(.007)
Covariates Included?	No	Yes	No	Yes	No	Yes	No	Yes
Constant	14.183***	6.733***						
	(.085)	(.397)						
R^2	.001	.288						
Observations	6126	6095	6126	6087	6126	6089	6128	6095

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$
[&]Results reported as marginal effects

Table 2.5
First Stage Regressions for 2SLS Model
Physical Education (Wave I) Regressed on Instrumental Variables

	Weekly Hours of Physical Education (Wave I)	
	(1)	(2)
Instrumental Variables		
Weekly Average PE in school (hours)	.791*** (.035)	
Weekly Average PE in school (hours) with at least 10 adolescents per school		.791*** (.036)
School Type		
Private	.031 (.049)	.033 (.049)
School Size		
Number of Teachers	-.000 (.001)	-.000 (.001)
Average Class Size	-.003 (.003)	-.003 (.003)
Number of Students on Roster (100)	.006 (.004)	.006 (.004)
Local Government Direct Expenditure per Capita ($100)	.020*** (.006)	.021*** (.006)
log[Block Group Median Household Income (in $10,000)]	.017 (.032)	.020 (.033)
County Crime	-.016** (.005)	-.016** (.005)
Annual Rainfall	-.002* (.001)	-.002* (.001)
Constant	.811*** (.215)	.790*** (.216)
R^2	.239	.240
F-Statistic	77.801	76.916
Observations	6693	6660

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects, school size (medium 401-1000 students, large 1001-4000 students), school type (private), urbanicity (suburban, rural)
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 2.6
Years of Completed Schooling in Wave IV Regressed on Physical Education (2SLS Model)

	2SLS[&]	
	Average PE in School	Average PE in School (at least 10 people in school)
	(1)	(2)
Predictor Variable (Standardized)		
Weekly Physical Education (Hrs.)	.304* (.140)	.312* (.140)
Covariates Included?	Yes	Yes
Constant	6.407*** (0.455)	6.398*** (0.456)
R^2	.246	.246
F-Statistic	77.801	76.916
Observations	5817	5786

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$
[&] Conditioned on type of school, size of school, local government direct expenditure on education per capita, log(block group median total family income), county crime, and annual rainfall

Table 2.7
Schooling Outcomes in Wave IV Regressed on Physical Education (2SLS Model)

	Graduate High School		Attend College		Graduate College	
	2SLS&		2SLS&		2SLS&	
	Average PE in School	Average PE in School (at least 10 people in school)	Average PE in School	Average PE in School (at least 10 people in school)	Average PE in School	Average PE in School (at least 10 people in school)
	(1)	(2)	(3)	(4)	(5)	(6)
Predictor Variable (Standardized)						
Weekly Physical Education (Hrs.)	.044**	.044**	.046**	.049**	.049	.050
	(.014)	(.014)	(.017)	(.017)	(.032)	(.032)
Covariates Included?	Yes	Yes	Yes	Yes	Yes	Yes
Constant	.352***	.353***	-.297***	-.307***	-1.179***	-1.173***
	(.064)	(.064)	(.077)	(.077)	(.090)	(.090)
R^2	.246	.246	.246	.246	.246	.246
F-Statistic	78.005	77.126	77.801	76.916	77.801	76.916
Observations	5815	5784	5817	5786	5817	5786

Note. *t* statistics in parentheses
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$
& Conditioned on type of school, size of school, local government direct expenditure on education per capita, log(block group median total family income), county crime, and annual rainfall

Appendix Table 2.1:
Highest Grade Completed in Wave IV Regressed on Physical Education (OLS)

	Highest Grade Completed (Wave IV)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Predictor Variable							
Weekly Physical Education (Hrs.)	-.059 (.042)	.014 (.032)	.002 (.031)	.078 (.066)	-.025 (.035)	-.008 (.045)	.012 (.038)
Covariates							
Female		.499*** (.059)	.470*** (.066)	.498*** (.059)	.501*** (.059)	.499*** (.059)	.500*** (.059)
Grade in Wave I							
8th		.130 (.093)	.132 (.093)	.212 (.155)	.126 (.092)	.131 (.093)	.130 (.092)
9th		.202* (.097)	.202* (.097)	.315* (.158)	.199* (.097)	.202* (.097)	.205* (.097)
10th		.501*** (.114)	.502*** (.114)	.601*** (.163)	.492*** (.114)	.504*** (.115)	.505*** (.114)
11th		.558*** (.118)	.560*** (.118)	.672*** (.152)	.553*** (.117)	.560*** (.119)	.558*** (.118)
12th		.890*** (.142)	.891*** (.142)	1.034*** (.161)	.885*** (.141)	.891*** (.142)	.892*** (.142)
Race/Ethnicity							
Hispanic		-.125 (.088)	-.124 (.088)	-.125 (.088)	-.149 (.127)	-.126 (.088)	-.125 (.088)
Black		.065 (.111)	.065 (.111)	.067 (.112)	-.058 (.116)	.065 (.111)	.065 (.111)
Asian		-.205^{+} (.122)	-.206^{+} (.123)	-.207^{+} (.124)	-.335* (.128)	-.204^{+} (.122)	-.208^{+} (.121)
Other		-.215** (.078)	-.216** (.078)	-.214** (.078)	-.226* (.110)	-.214** (.078)	-.216** (.078)
US born		.055 (.121)	.056 (.121)	.057 (.121)	.051 (.120)	.056 (.121)	.052 (.121)
Parents US born		-.365** (.113)	-.366** (.113)	-.365** (.113)	-.366** (.112)	-.365** (.113)	-.366** (.113)
Live with both parents		.232*** (.058)	.232*** (.058)	.235*** (.058)	.231*** (.058)	.233*** (.058)	.231*** (.058)
English spoken at home		-.173^{+} (.089)	-.172^{+} (.089)	-.170^{+} (.091)	-.165^{+} (.090)	-.174^{+} (.090)	-.173^{+} (.089)
Mother's Education		.186*** (.017)	.186*** (.017)	.186*** (.017)	.186*** (.017)	.187*** (.017)	.186*** (.017)

Appendix Table 2.1 (Continued):
Highest Grade Completed in Wave IV Regressed on Physical Education (OLS)

Self-reports of GPA at beginning of school year						
English	.220***	.220***	.221***	.218***	.220***	.220***
	(.039)	(.039)	(.039)	(.039)	(.039)	(.039)
Math	.219***	.219***	.218***	.219***	.219***	.219***
	(.031)	(.031)	(.031)	(.031)	(.031)	(.031)
Humanities	.257***	.257***	.257***	.258***	.257***	.257***
	(.034)	(.034)	(.034)	(.034)	(.034)	(.034)
Science	.223***	.223***	.223***	.222***	.223***	.224***
	(.041)	(.041)	(.041)	(.040)	(.041)	(.041)
Mother's age at birth	.046***	.046***	.047***	.046***	.046***	.046***
	(.006)	(.006)	(.006)	(.006)	(.006)	(.006)
Birth weight (lb)	.020	.020	.020	.019	.020	.020
	(.017)	(.017)	(.017)	(.017)	(.017)	(.017)
log(total family income in1994)	.319***	.319***	.318***	.319***	.309***	.320***
	(.046)	(.046)	(.046)	(.046)	(.053)	(.046)
Can't pay bills	-.143*	-.143*	-.143*	-.144*	-.143*	-.142*
	(.070)	(.070)	(.070)	(.070)	(.070)	(.071)
Welfare recipient	-.218**	-.218**	-.218**	-.220**	-.218**	-.217**
	(.069)	(.069)	(.069)	(.069)	(.069)	(.069)
Mother is obese	-.194**	-.195**	-.192**	-.194**	-.194**	-.195**
	(.070)	(.070)	(.070)	(.070)	(.070)	(.070)
Father is obese	.157+	.155+	.157+	.162+	.157+	.159+
	(.089)	(.089)	(.089)	(.089)	(.089)	(.090)
Parents' marital status						
Single/Never Married/Widowed/ Separated	.129	.128	.131	.131	.129	.130
	(.080)	(.080)	(.081)	(.080)	(.080)	(.080)
Divorced	.087	.088	.088	.087	.088	.087
	(.076)	(.076)	(.075)	(.075)	(.076)	(.076)
Weight status						
Overweight	-.101	-.101	-.104	-.099	-.103	-.165+
	(.072)	(.072)	(.073)	(.073)	(.072)	(.097)
Obese	-.073	-.073	-.073	-.072	-.072	.012
	(.090)	(.090)	(.090)	(.090)	(.090)	(.132)
Survey Taken in Summer	-.026	-.027	-.025	-.022	-.026	-.026
	(.060)	(.060)	(.060)	(.060)	(.060)	(.060)

Appendix Table 2.1 (Continued):
Highest Grade Completed in Wave IV Regressed on Physical Education (OLS)

Interactions							
Gender							
Physical Activity X			.025				
Female			(.036)				
Grade							
Physical Activity X				-.048			
Grade 8				(.079)			
Physical Activity X				-.069			
Grade 9				(.077)			
Physical Activity X				-.060			
Grade 10				(.080)			
Physical Activity X				-.076			
Grade 11				(.083)			
Physical Activity X				-.132			
Grade 12				(.098)			
Race/Ethnicity							
Physical Activity X					.022		
Hispanic					(.057)		
Physical Activity X					.094		
Black					(.071)		
Physical Activity X					$.113^{+}$		
Asian					(.067)		
Physical Activity X					.010		
Other					(.057)		
Income							
Physical Activity X						.008	
log(Total family income in 1994)						(.013)	
Weight Status							
Physical Activity X							.052
Overweight							(.057)
Physical Activity X							-.068
Obese							(.065)
Constant	14.183^{***}	6.733^{***}	6.748^{***}	6.622^{***}	6.796^{***}	6.757^{***}	6.739^{***}
	(.085)	(.397)	(.393)	(.401)	(.378)	(.403)	(.397)
R^2	.001	.288	.288	.288	.289	.288	.288
Observations	6126	6095	6095	6095	6095	6095	6095

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 2.2: Educational Attainment in Wave IV Regressed on Physical Education (Odds Ratio)

	Highest Grade Completed		Graduate High School[&]		Attend College[&]		Graduate College [&]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Predictor Variable (Standardized)								
Weekly Physical Education (Hrs.)	-.059	.014	0.941	1.049	0.994	1.056^{+}	0.980	1.042
	(.042)	(.032)	(0.038)	(0.041)	(0.033)	(0.033)	(0.039)	(0.045)
Covariates Included?	No	Yes	No	Yes	No	Yes	No	Yes
Constant	14.183***	6.733***						
	(.085)	(.397)						
R^2	.001	.288						
Observations	6126	6095	6126	6087	6126	6089	6128	6095

Note. Exponentiated coefficients. Robust standard errors in parentheses.

Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects

$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

[&]Results reported as odds ratio

Appendix Table 2.3
Summary Statistics for Additional Instrumental Variables Attempts in 2SLS Model

	Mean/%	Std. Dev	Min	Max
Instrumental Variables				
Weekly Average PE in school (hours)	1.22	.50	.23	2.86
Weekly Average PE in school (hours) with at least 10 adolescents per school	1.22	.50	.26	2.86
Other Potential Instrumental Variables				
Athletic/Physical resources available at school	41.41%			
Athletic/Physical resources available at school or nearby school	47.39%			
Recreation Center available at school	30.54%			
State requires PE	62.16%			

Appendix Table 2.4
Correlation Matrix for Instrumental Variables in 2SLS Model and Physical Education

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Weekly Physical Education (Hrs.)	1.00						
Other Potential Instrumental Variables							
Athletic/Physical resources available at school	.07***	1.00					
Athletic/Physical resources available at school or nearby school	.09***	.89***	1.00				
Recreation Center available at school	.00	.19***	.16***	1.00			
State requires PE	-.03*	.26***	.19***	.04***	1.00		
Instrumental Variables							
Weekly Average PE in school (Hrs.)	.38***	.16***	.22***	.01	-.05***	1.00	
Weekly Average PE in school (Hrs.) with at least 10 adolescents per school	.38***	.16***	.22***	.01	-.05***	1.00	1.00

* $p < .05$, ** $p < .01$, *** $p < .00$

Appendix Table 2.5
First Stage Regressions for 2SLS Model - Physical Education (Wave I) Regressed on Instrumental Variables

	Hours of Physical Education (Wave I)			
Athletic/Physical resources available at school	.184^{+} (.096)			
Athletic/Physical resources available at school or nearby school		.199* (.089)		
Recreation Center available at school			-.060 (.095)	
State requires PE				.053 (.144)
Private School	-.133 (.133)	-.100 (.133)	-.116 (.133)	-.278* (.139)
School Size				
Number of Teachers	.001 (.003)	.001 (.003)	.002 (.003)	.001 (.003)
Average Class Size	-.012 (.009)	-.010 (.009)	-.014 (.009)	-.010 (.010)
Number of Students on Roster (100)	-.007 (.014)	-.006 (.014)	-.009 (.014)	-.005 (.016)
Local Government Direct Expenditure per Capita ($100)	.071** (.024)	.071** (.024)	.078*** (.023)	.064** (.020)
log(Block Group Median Total Family Income)	.090 (.064)	.077 (.060)	.083 (.060)	.047 (.073)
County Crime	-.029^{+} (.015)	-.032* (.016)	-.030^{+} (.016)	-.040* (.017)
Annual Rainfall	-.008** (.003)	-.007* (.003)	-.007* (.003)	-.007* (.003)
Constant	1.762*** (.406)	1.704*** (.414)	1.800*** (.402)	1.904*** (.422)
R^2	.170	.171	.166	.172
F-Statistic	7.935	7.776	6.767	7.078
Observations	6579	6579	6695	5912

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects, school size (medium 401-1000 students, large 1001-4000 students), school type (private), urbanicity (suburban, rural)
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 2.6
Educational Attainment in Wave IV Regressed in Physical Education (2SLS)

	OLS	2SLS[&]			
		Athletic/ Physical resources available at school	Athletic/ Physical resources available at school or nearby school	Recreation Center available at school	State requires PE
	(1)	(2)	(3)		
Predictor Variable (Standardized)					
Weekly Physical Education (Hrs.)	.014	.085	.104	-.093	-.234
	(.032)	(.162)	(.160)	(.196)	(.226)
Covariates Included?	Yes	Yes	Yes	Yes	Yes
Constant	6.733***	6.683***	6.660***	6.901***	7.222***
	(.397)	(.445)	(.444)	(.455)	(.504)
R^2	.288	.181	.182	.177	.184
F-Statistic		7.935	7.776	6.767	7.078
Observations	6095	5714	5714	5819	5135

Note. Robust standard errors in parentheses.
Covariates include: female, race (Hispanic, black, Asian, other), birth weight, parents' marital status (married, single/never married/widowed/separated, divorced), mother's education, mother's age at birth, if US born, if parents are US born, if child lives with both parents, if English is spoken at home, self reports of GPA at beginning of the school year (English, math, humanities, science), log of total family income in 1994, if parents can pay their bills, if parents receive welfare, if mother is obese, if father is obese, weight status (healthy/normal, overweight, obese), if survey was conducted during summer months, grade fixed effects
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$
[&]Conditioned on type of school, size of school, local government direct expenditure on education per capita, log(block group median total family income), county crime, and annual rainfall

CHAPTER 3:

Varsity Sports Participation and Academic Performance

Research on the benefits of participating in sports has primarily been derived from the organized extracurricular activities literature, which often draws from the Bioecological Theory of Development (Bronfenbrenner & Morris, 2006). Bronfenbrenner and Morris stress the importance of settings where adolescents can experience "proximal processes," which are the engines for development that can promote or undermine positive development. Critical aspects of sports include opportunities for enrichment and challenge, supportive relationships with adult leaders, positive peer networks, and a chance for choice and voice (Eccles & Gootman, 2002; Vandell, Larson, Mahoney, & Watts, 2015).

Correlational studies

As researchers have examined the benefits of sports participation, particular interest has been focused on their potential educational benefits. Longitudinal correlational research has shown a positive relationship between sports participation and educational outcomes (Farb & Matjasko, 2012; Feldman & Matjasko, 2005; Trudeau & Shephard, 2008). For example, in a longitudinal sample of 586 Western New York adolescents, when controlling for prior grades, gender, race, age, and socioeconomic status, female athletes were found to have reported higher grades than female nonathletes (Miller, Melnick, Barnes, Farrell, & Sabo, 2005). High school sports participation has also been found to be positively associated with later educational performance when accounting for a host of demographic and adolescent factors (Lleras, 2008; Troutman & Dufur, 2007).

Person- or pattern-centered approaches using longitudinal data have also been used to examine the relationship between sports participation and education. In these approaches, involvement in team sports is also positively associated with educational outcomes. Eccles, Barber, Stone, and Hunt (2003) used the Michigan Study of Adolescent Life Transitions to find involvement in team sports to be a factor for academic outcomes, such as a higher than expected 12^{th} grade GPA. Involvement in team sports was also linked to an increased likelihood to attend and graduate from college. Metzger and colleagues (2009) found clusters that include high levels of sports participation to be highly associated with increases in GPA after controlling for gender, age, and ethnicity.

In various comprehensive reviews of the literature, sports participation has generally been positively linked with numerous educational outcomes using survey data and correlational methods (Farb & Matjasko, 2012; Feldman & Matjasko, 2005; Trudeau & Shephard, 2008). Although the research on the associations between sports and education has been promising, these correlational methods are limited by the quality and nature of the data. Much of the extant literature on sports participation used methods that are unable to account for unobservable factors, which may bias the relationship between sports participation and educational outcomes (Farb & Matjasko, 2012). The inability to account for these unobservable factors, such as selection into sports programs, ability, background, and general motivation, does not provide an unbiased or causal estimate of sports on education.

Studies using natural experiments

One potential avenue for obtaining an unbiased estimate of sports participation on educational outcomes is to examine cases where participation in sports has been banned in schools. In an interesting set of circumstances, secondary school teachers in Montreal, Canada refused to supervise sports-related extracurricular activities as a pressure tactic in the context of collective bargaining negotiations in 1999. However, this ban was imposed differentially across schools, allowing researchers to examine the effect of participation in school sports. Pabayo, O'Loughlin, Gauvin, Paradis, and Gray-Donald (2006) used a sample of 7th grade students before and after the ban across seven schools that fully implemented the ban and three schools that did not fully implement the ban. They found that ending the ban was associated with increased physical activity in adolescents. However, the researchers limited their outcome measures to physical activity and did not consider the potential educational benefits that ending the ban might have had.

Studies using instrumental variables

Instrumental variables are another method for obtaining unbiased estimates of the relationship between sports participation on educational outcomes. Instrumental variables are exogenous variables that are correlated with sports participation and are used to estimate adolescent sports participation, which can then be used to predict educational outcomes such as years of completed schooling in a two-stages least squares model. In this framework, adolescent sports participation can be considered somewhat analogous to the treatment group in a randomized control trial as this method obtains an unbiased or causal estimate of sports participation on educational outcomes.

Barron, Ewing, and Waddell (2000) used this instrumental variable approach using the National Longitudinal Survey of Youth (NLSY) and the National Longitudinal Study of the High School Class of 1972 to estimate the causal impact of sports participation on educational attainment and wages for boys. They used the type of school, school size, parent income, adolescent health, library books-per-student, faculty-to-student ratio, and demographic information about the adolescent’s county of residence as instruments to predict sports participation. Under the assumption that these instruments are exogenous and successful in accounting for selection into sports participation, they found sports participation to not have an effect on educational attainment. However, some may argue that the instruments used in the analysis are not exogenous and are not good instruments, regardless of their statistical significance. In particular, there may be additional factors, such as the availability of sports programs in a given school, that are unaccounted for in the first stage of the model and fails to meet the exclusion restriction. This in turn results in a biased estimate of sports participation. Additionally, these results are for a nationally representative sample of boys who were teenagers in the 1970s and the extent to which these results are applicable for later generations and for girls are questionable.

Using the NLSY, Stevenson (2010) also used a stronger instrumental variables strategy to estimate a causal link between sports participation and educational attainment for girls. Between 1972 and 1978, high schools increased their female sports participation rates in order to comply with Title IX. By using Title IX as an instrument, Stevenson is able to use variation in the level of boys' sports participation across states before Title IX to instrument for the change in girls' sports participation using an analysis of differences in outcomes across states between pre- and post-Title IX implementation. Stevenson found sports participation to increase years of completed schooling by .55 years and increase the probability of graduating high school by 5.7%, attending college for at least one year by 12.1%, attending college for at least four years by 5.4%, and attending post-graduate education by 4.4% for females. Similarly to Barron et al. (2000), the extent to which these results are applicable for later generations and for males is questionable as sports participation rates between males and females in different sports may differ.

An important strength of using instrumental variables is that if its assumptions are met, it produces unbiased estimates, which can be analogous estimates obtained in a randomized control trial. However, this estimate is not relevant across all adolescents—they are relevant only for adolescents whose behaviors would change as a function of a potential policy lever. For example, if a school received an increase in funding intended to change the availability of sports programs in schools, the estimates using instrumental variables would be applicable only for students who would be able to participate in sports because of this increase in funding and would not have been able to participate without this funding. Estimates using the instrumental variable strategy would be irrelevant for students who do not enjoy participating in sports and would not participate in school sports programs even with increased funding. They would also be irrelevant for students that would be participating in sports regardless of increased funding.

Studies using fixed effects adjustments

Another alternative in examining the educational benefits of sports participation is through the use of fixed effects to account for time-invariant observable and unobservable factors that can bias the relationship. Lipscomb (2007) used a fixed effects strategy to test whether sports participation provides an immediate return to student learning. By comparing an individual to him or herself across different time points, Lipscomb exploited changes in an individual's participation in sports to assess the association between sports participation and test scores in math and science while controlling for time-invariant individual characteristics such as gender and race. He found participation in sports to be associated with a 2% percent increase in math and science scores. Although an individual fixed effects method does not account for unobservable factors that change over time, an important strength of this method accounts for any unobservable time-invariant self-selection factors such as ability, background, and general motivation (Lipscomb, 2007). Furthermore, the source of identification comes from adolescents who join or quit sports in a given year, which allows for the analysis of the change in academic performance that is associated with an additional year of sports participation.

Another potential point of concern across the extant literature is the nature of sports participation. The measure for sports participation in these studies does not often specify if sports participation occurs solely in the school environment or if it also pertains to out-of-school sports participation. In particular, there is a huge market for private sports participation, such as Amateur Athletic Union (AAU) for basketball, and American Youth Soccer Organization (AYSO), among others. As prior research often struggles to separate school-based sports participation with extramural sports, it may be difficult to understand the potential educational benefits of sports participation as extramural sports participation can be a function of more affluent neighborhoods and families. It may also be difficult to make policy-driven decisions regarding the potential benefits of adolescent sport participation if it is unclear if association between sports and education are available in school-based sports programs, privately funded sports programs, or both based on longitudinal survey data. As such, it is important to understand how school-based sports are important and potentially beneficial for adolescents.

It is possible that school-based sports participation might have a greater educational benefit than extramural sports participation. In most schools, school-based sports participation is often predicated by a minimum GPA requirement. Athletically skilled students who could participate in extramural sports without any concern for their academic performance would have to maintain their grades in order to play for their school sports teams. Furthermore, many states require adolescents to take a physical education class to fulfill their high school graduation requirements and participation in a varsity team sport can replace the state-mandated physical education requirement in many schools. Varsity sports participation may have greater educational benefits than other types of sports participation but their educational benefits have not been fully explored.

This study examines the relationship between varsity sports participation and educational performance using high school transcript data that reports grades in different classes and varsity sports participation across four years of high school and individual fixed effects. The use of individual fixed effects takes advantage of the four years of data provided in the high school transcripts by estimating the change in academic performance that is associated with an additional year of sports participation. By establishing this relationship, the extent to which participating in school-based sports activities can be beneficial for educational outcomes such as grades in curricular classes such as English, mathematics, and science can be explored.

Data

The data are drawn from the National Longitudinal Study of Adolescent Health (Add Health), a prospective longitudinal study of a nationally representative sample of adolescents in grades 7 through 12 in the US during the 1994-1995 school year who were followed until 2008. This study draws data regarding varsity sports participation for each year to predict educational performance via high school grades from high school transcripts released by Add Health sample members during Wave III.

The analysis consists of the sample of 12,004 adolescents who agreed to release their high school transcripts during Wave III. The transcripts report academic performance (as measured by grades on a 4-point scale) in classes such as English, humanities, mathematics, science, and physical education as well as the overall grade point average (GPA) at the end of the year. Transcripts also report participation in varsity sports and if adolescents failed certain classes in each year of high school. In order to fully take advantage of the transcript data, each adolescent will have four linkable records (i.e., one for each year between 9th and 12th grade). The important source of identification comes from adolescents whose sports participation changes from one year to the next. Out of the 12,004 adolescents in the sample, 9,771 never participated in a varsity sport and 194 participated in a sport all four year of high school. Due to the lack of variation in varsity sports participation, these adolescents are excluded from in the individual fixed effects models. The individual fixed effects estimates take advantage of 2,039 adolescents whose participation in varsity sports vary over the four years of high school. Table 3.1 provides descriptive information for the full sample for the main predictor variable, outcomes of interest, and covariates.

Analytic Strategy

To understand the role sports programs for educational performance, data on participation in varsity sports was used to predict educational performance (grades in academic courses). The models for this study estimate the association between participation in varsity sports on educational performance. The estimated ordinary least squares (OLS) model typically used is:

$$Outcome_i = \beta_0 + \beta_1(Sports)_i + \delta' X_i + \beta_2(year) + \varepsilon_i \quad (1)$$

where $Outcome_i$ reflects the educational performance outcomes (as measured by grade point average) for adolescent i. $Sports_i$ corresponds to if an adolescent participated in a varsity sport, and X_i captures the vector of demographic, family, and individual characteristics covariates. ε_i is the error term. Because in our data, there are four observations for each adolescent, a dummy variable (*year*) that indicates if the case is for 9th, 10th, 11th, or 12th grade is included and standard errors are clustered at the individual level. However, the typical OLS model fails to control for unobservable characteristics that can influence both sports participation and educational performance, such as ability, background, and motivation.

Given that the transcripts provide four cross-sections of varsity sports participation and academic performance for a given individual, an individual fixed effects model will estimate the association between participation in varsity sports on educational performance and attainment. An important strength of this method is that it compared an observation of an individual to a different observation of the same individual at a different point in time. By comparing the individual to his or herself at a different point in time, this accounts for any unobservable time-invariant factors such as ability, background, and motivation. The estimated individual fixed effects model is:

$$Outcome_i = \beta_0 + \beta_1(Sports)_i + \delta' X_i + \beta_2(year) + \omega_i + \varepsilon_i \quad (1)$$

where $Outcome_i$ reflects the educational performance outcomes (as measured by grade point average) for adolescent i. $Sports_i$ corresponds to if an adolescent participated in a varsity sport, and X_i captures the vector of demographic, family, and individual characteristics covariates. ω_i controls for the time invariant unobserved individual factors and ε_i is the error term. Because there are four cases for each adolescent, a dummy variable (*year*) that indicates if the case is for 9th, 10th, 11th, or 12th grade is included and standard errors are clustered at the individual level. It is important to note that some of the factors in X_i would be omitted as they would not vary over time (e.g., gender, race/ethnicity, if English is spoken at home).

Measures

Participation in Varsity Sports.

During Wave III of the Add Health study when the adolescents were between the ages of 18 to 26, they were asked to sign a Transcript Release Form to request official transcripts from the high schools they last attended. Transcripts report participation in "competitive sports" in each year of high school, which include individual sports, team sports, gymnastics, track and field, and aquatics.

In some schools, participation in sports can only be substituted for physical education course credit if the adolescents participate in at the varsity level, which in some instances can be restricted to adolescents with a higher level of skills or seniors. Given that sports participation is determined through transcripts rather than a self-report; these results using administrative data may provide a more conservative estimate of sports participation than the extant literature. This measure does not include participation in non-varsity level school sports or participation in extracurricular sports participation outside of the school. The average participation rate in varsity sports for the sample was 8% and participation for males (11%) was higher than for females (6%).

Educational Performance.

Official transcripts from the high school adolescents last attended were obtained via a Transcript Release Form and report grades earned at the end of the year for each year in high school. Transcripts were not collected from two original Add Health schools that served only special education students and did not keep transcript records. However, a few respondents who entered the Add Health sample through one of these two schools do have transcript records because the last school they attended kept transcript records.

The transcript records were coded using the Classification of Secondary School Curriculum (CSSC), allowing for a standardized scale across different schools. Given this standardized coding, grades earned in English/language arts, history/social sciences, mathematics, sciences, foreign language courses and physical education classes, as well as the overall grade point average (GPA) between grades 9 and 12 are available as outcomes. Overall GPA was calculated by taking the average of the grades in the academic subjects (English/language arts, history/social sciences, mathematics, sciences, and foreign language courses) for each year. Overall grade point average averaged 2.38 on a 4-point scale (Table 3.1).

Covariates.

Adolescent demographic, family, school, and individual characteristics that may bias the relationship in the Add Health data was included the analysis. An important strength of the Add Health is the depth and breadth of information collected in the parent interview. The selection of control variables was driven by the goal of selecting measures that might be confounded with physical education but not a part of the mechanism by which varsity sports participation might affect educational performance. A full list of these control measures and their summary statistics is provided in Table 3.1.

Adolescent and maternal background characteristics that are used as covariates include: female, race (Hispanic, Black, Asian, other), birth weight, mother's education, mother's age at birth, if US born, if parents are US born, and if English is spoken at home. These covariates are time invariant and are not included in the individual fixed effects models.

Additional covariates include participation in alternative school-based extracurricular physical activity, such as participation in the school dance team or the school's marching band, and a school year dummy to indicate if the observation was in either grade 9, 10, 11, or 12.

Results

Descriptive Statistics

Table 3.1 provides descriptive information for the full sample's covariates. The sample was 51% female, 35% white, 23% black, 20% Hispanic, 9% Asian, and 13% Other. On average, 8% of the cases participated in sports. Average overall GPA was 2.40 (standard deviation = .97) out of 4.

Table 3.2 shows the correlations between varsity sports participation and the educational performance outcomes. Participating in varsity sports was not related to overall GPA, but was positively related to GPA in English, humanities, and physical education but the correlations are never greater than .10. Participating in varsity sports was also negatively related to math but the correlation is also not greater than .10.

The results for the OLS regression where overall GPA was regressed on participation in varsity sports are shown on Table 3.3. Participating in varsity sports was associated with a .089 (3.7%) increase in overall GPA and the association was greater for males (.105 or 4.7%) than for females (.070 or 2.7%). OLS regression results with the full set of covariates are presented in Appendix Table 3.1

Table 3.3 also presents regression results using individual fixed effects (FE). These regressions estimate the associations between changes in participation in varsity sports through high school and changes in overall GPA. Students who never participated in varsity sports and participated in varsity all four years are not included. In the presence of individual FE adjustments, there was no association between varsity sports participation and overall GPA, even when the samples were examined by gender.

In addition to overall GPA, the association between grades in the core academic and physical education classes and varsity sports participation are examined in an OLS regression in Table 3.5. Participation in varsity sports was associated with an increase in GPA in English (.132 or 5.4%), humanities (.144 or 5.5%), and science classes (.051 or 2.2%). Participation in varsity sports was also associated with an increase in GPA in physical education classes (.294 or 9.3%)

OLS regression results with the full set of covariates for each of the outcomes are presented in Appendix Tables 3.2-3.6

The associations between grades in the core academic and physical education classes and varsity sports participation using individual FE adjustments are presented in Table 3.6. Participation in varsity sports was associated with an increase in GPA in foreign language (.063 or 2.4%) and in in physical education classes (.093 or 2.9%) Participation in varsity sports also shows a marginally significant association with GPA in English (.031 or 1.3%) Regression results using individual FE adjustments with the full set of covariates for each of the outcomes are presented in Appendix Tables 3.2-3.6.

Individual FE results for core academic and physical education classes are then presented separately for females (Table 3.7) and males (Table 3.8). For females, there was no significant association between varsity sports participation and grades. However, there was also a marginally significant relationship between varsity sports participation and foreign language grades (.077 or 2.9%). For males, there was a significant positive association between varsity sports participation and grades in English (.055 or 2.2%) and physical education classes (.137 or 4.3%).

Discussion

The results demonstrate the importance of varsity sports participation on educational performance. It appears that adolescents receive a slight benefit in their overall GPA from varsity sports participation based on the OLS regressions. However, these benefits appear to fade with the inclusion of individual FE adjustments. An individual FE adjustment uses changes in varsity sports participation from one year to the next within a student to estimate the associations between varsity sports participation and overall GPA. As such, these adjustments account for potential unobservable time invariant factors that may have biased the relationship between varsity sports participation and educational performance in the OLS model. The results also suggest that males and females are differentially affected by varsity sports participation in different subjects. In sum, the OLS results and results using individual fixed effects adjustments indicate that participation in varsity sports is not detrimental to academic performance.

However, the positive association between varsity sports participation and physical education class GPA in both the OLS and regressions using individual FE suggest a potential story in which low-performing adolescents who are skilled at sports receive slight unjustified boosts in their GPA. Schools often have a minimum GPA requirement to participate in varsity sports and if physical education class grades are included in the calculations for overall GPA, these low-performing male athletes may receive boosts in GPA in their physical education classes—classes whose teachers may also be the coach of a given varsity sports team. If this is the case, the generally positive associations between varsity sports participation and academic performance may actually be marred by grade manipulation rather than aspects of sports that can be opportunities for enrichment and challenge.

Appendix Table 3.7 examines the potential benefits of varsity sports participation in overall GPA if physical education class GPA is included in the measure for overall GPA. In the OLS models, participation in varsity sports was associated with a .144 (6.0%) increase in overall GPA and this association was slightly greater for males (.179 or 8.1%) than females (.095 or 3.7%). In the individual FE models, participation in varsity sports was associated with a .041 or 1.7% increase in overall GPA and this association is driven by males (.066 or 3.0%). As such, it is possible that athletes in varsity sports receive grade inflation in their physical education classes that helps them pass the minimum GPA threshold required to participate in sports—the academic benefits of varsity sports participation for these students would be based on their athletic ability rather than the skills and behaviors that adolescents typically learn through the school system.

Future research should seek to understand the mechanisms that explain the association between varsity sports and academic performance. Among others, if there is evidence of grade manipulation to permit varsity athletes to play sports, the motivation as to why teachers allow grade manipulation should be fully explored. Other potential mechanisms worth pursing include improvements in classroom behaviors as unruly classroom behaviors can result in suspensions from sports games, improved social networks, and feelings of attachment to the school.

Although the individual fixed effects controls for observable and unobservable time invariant individual factors that would bias the relationship between varsity sports participation and educational performance and produce an extremely conservative estimate, the relations are still correlational in nature. Future research should seek to estimate the causal impact of varsity sports participation on educational performance through experimental or quasi-experimental methods.

Table 3.1: Summary Statistics

	Full Sample (N=12,004)		Females Only (N=6,073)		Male Only (N=5,931)	
	Mean/%	Std. Dev.	Mean/%	Std. Dev.	Mean/%	Std. Dev.
Outcome Variables (GPA)						
Overall	2.40	.97	2.56	.94	2.22	.98
English	2.45	1.08	2.65	1.04	2.23	1.09
Foreign Language	2.64	1.17	2.80	1.12	2.42	1.19
Humanities	2.60	1.13	2.74	1.09	2.45	1.16
Math	2.23	1.17	2.34	1.15	2.10	1.17
Science	2.36	1.16	2.49	1.13	2.21	1.18
Physical Education	3.16	1.09	3.11	1.11	3.21	1.07
Predictor Variable						
Varsity Sports Participation	8.23%		6.12%		10.57%	
Covariates						
Dance/Band Participation	4.82%		6.64%		2.79%	
Year						
9th	25.00%		25.00%		25.00%	
10th	25.00%		25.00%		25.00%	
11th	25.00%		25.00%		25.00%	
12th	25.00%		25.00%		25.00%	
Female	50.59%					
Gender/Ethnicity						
Hispanic	19.65%		18.89%		20.44%	
Black	22.88%		23.88%		21.85%	
Asian	8.91%		8.15%		9.70%	
Other	13.43%		13.17%		13.69%	
US Born	90.02%		90.22%		89.81%	
Parents US Born	82.24%		82.97%		81.47%	
English Spoken at Home	88.48%		88.70%		88.25%	
Mom Age at Birth	25.24	5.34	25.20	5.30	25.28	5.38
Birthweight (oz.)	7.22	1.41	7.07	1.37	7.36	1.43

Table 3.2: Correlation Matrix between Main Predictor and Outcomes Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Outcome Variables (GPA)								
Overall	1.00							
English	.86***	1.00						
Foreign Language	.83***	.61***	1.00					
Humanities	.84***	.66***	.59***	1.00				
Math	.83***	.59***	.60***	.56***	1.00			
Science	.86***	.65***	.60***	.64***	.63***	1.00		
Physical Education	.54***	.48***	.42***	.47***	.42***	.48***	1.00	
Predictor Variables								
Varsity Sports Participation	.00	.01*	-.01	.02***	-.01**	-.01	.08***	1.00

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 3.3: Overall GPA Regressed on Varsity Sports (OLS and Individual Fixed Effects)

	OLS			Individual FE		
	Full Sample	Female Only	Male Only	Full Sample	Female Only	Male Only
Predictor Variable						
Varsity Sports Participation	.089***	.070*	.105***	-.005	-.011	.007
	(.020)	(.030)	(.027)	(.014)	(.020)	(.019)
Covariates						
Dance/Band Participation	.196***	.197***	.196***	-.034	-.083	.042
	(.025)	(.029)	(.050)	(.040)	(.050)	(.069)
Year (9th grade= reference)						
10th	-.076***	-.061***	-.094***	-.091***	-.064**	-.112***
	(.007)	(.009)	(.010)	(.015)	(.022)	(.021)
11th	-.048***	-.017+	-.083***	-.114***	-.090***	-.132***
	(.008)	(.010)	(.011)	(.017)	(.025)	(.024)
12th	.091***	.127***	.050***	-.027	.047	-.085**
	(.009)	(.012)	(.013)	(.020)	(.030)	(.027)
Constant	1.828***	2.244***	1.753***	2.389***	2.564***	2.252***
	(.070)	(.093)	(.101)	(.011)	(.017)	(.015)
R^2	.110	.091	.078	.010	.015	.011
Observations	45218	23912	21306	7894	3443	4451

Note. Standard errors in parentheses

$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Covariates in OLS models not shown include: female, race/ethnicity (black, Hispanic, Asian, other), US Born, Parents born in US, English spoken at home, mother's age a birth, and birthweight

Table 3.5: Academic Class GPA Regressed on Varsity Sports Full Sample (OLS)

	English	Foreign Language	Humanities	Mathematics	Science	Physical Education
Predictor Variable						
Varsity Sports Participation	.132***	.037	.144***	.027	.051*	.294***
	(.022)	(.031)	(.024)	(.024)	(.025)	(.023)
Covariates						
Dance/Band Participation	.182***	.255***	.222***	.158***	.171***	.452***
	(.027)	(.038)	(.029)	(.032)	(.031)	(.022)
Year (9th grade= reference)						
10th	-.004	-.039*	-.065***	-.137***	-.061***	.067***
	(.009)	(.016)	(.012)	(.010)	(.011)	(.012)
11th	.012	-.028	.048***	-.166***	-.072***	.050**
	(.010)	(.019)	(.012)	(.012)	(.013)	(.016)
12th	.109***	.037	.197***	-.079***	.078***	.094***
	(.011)	(.025)	(.013)	(.015)	(.016)	(.018)
Covariates Included?	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.796***	2.214***	1.909***	1.750***	1.888***	2.873***
	(.075)	(.106)	(.080)	(.080)	(.083)	(.087)
R^2	.095	.078	.085	.075	.084	.079
Observations	43570	20126	38924	39841	35640	26873

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$
Covariates not shown include: female, race/ethnicity (black, Hispanic, Asian, other), US Born, Parents born in US, English spoken at home, mother's age a birth, and birthweight

Table 3.6: Academic Class GPA Regressed on Varsity Sports Full Sample (Individual Fixed Effects)

	English	Foreign Language	Humanities	Mathematics	Science	Physical Education
Predictor Variable						
Varsity Sports Participation	.031^{+}	.063*	.022	-.021	.010	.093**
	(.018)	(.032)	(.021)	(.022)	(.024)	(.029)
Covariates						
Dance/Band Participation	.033	.105	.075	-.153*	-.144*	-.021
	(.058)	(.108)	(.067)	(.062)	(.071)	(.066)
Year (9th grade= reference)						
10th	-.029	-.158***	-.020	-.170***	-.082**	.093***
	(.021)	(.037)	(.025)	(.024)	(.026)	(.028)
11th	-.070**	-.284***	.077**	-.257***	-.251***	.067^{+}
	(.023)	(.043)	(.025)	(.026)	(.029)	(.035)
12th	-.033	-.407***	.169***	-.244***	-.183***	.088*
	(.025)	(.060)	(.028)	(.034)	(.037)	(.041)
Constant	2.422***	2.651***	2.520***	2.288***	2.367***	3.091***
	(.015)	(.030)	(.018)	(.017)	(.021)	(.019)
R^2	.002	.036	.013	.023	.020	.012
Observations	7583	3703	6786	7129	6157	5340

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 3.7: Academic Class GPA Regressed on Varsity Sports Female Only (Individual Fixed Effects)

	English	Foreign Language	Humanities	Mathematics	Science	Physical Education
Predictor Variable						
Varsity Sports Participation	.004	.077^{+}	.038	-.046	-.003	.037
	(.027)	(.040)	(.031)	(.031)	(.035)	(.046)
Covariates						
Dance/Band Participation	.017	.023	-.003	-.181*	-.164^{+}	.002
	(.068)	(.107)	(.089)	(.076)	(.087)	(.075)
Year (9th grade= reference)						
10th	-.021	-.187***	-.028	-.149***	-.078*	.042
	(.032)	(.045)	(.037)	(.035)	(.037)	(.045)
11th	-.061^{+}	-.298***	.064^{+}	-.206***	-.295***	.056
	(.033)	(.056)	(.036)	(.039)	(.042)	(.057)
12th	.004	-.392***	.197***	-.135**	-.174**	.148*
	(.037)	(.081)	(.040)	(.052)	(.056)	(.071)
Constant	2.673***	2.913***	2.675***	2.393***	2.550***	3.054***
	(.023)	(.038)	(.026)	(.026)	(.031)	(.030)
R^2	.002	.043	.018	.018	.030	.007
Observations	3329	1805	2995	3088	2723	2151

Note. Standard errors in parentheses

$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Covariates not shown include: female, race/ethnicity (black, Hispanic, Asian, other), US Born, Parents born in US, English spoken at home, mother's age a birth, and birthweight

Table 3.8: Academic Class GPA Regressed on Varsity Sports Male Only (Individual Fixed Effects)

	English	Foreign Language	Humanities	Mathematics	Science	Physical Education
Predictor Variable						
Varsity Sports Participation	.055*	.043	.012	.011	.017	.137***
	(.026)	(.051)	(.030)	(.031)	(.034)	(.037)
Covariates						
Dance/Band Participation	.058	.467	.218*	-.132	-.083	-.086
	(.111)	(.324)	(.098)	(.110)	(.124)	(.126)
Year (9th grade= reference)						
10th	-.038	-.123*	-.010	-.189***	-.085*	.127***
	(.029)	(.060)	(.035)	(.034)	(.036)	(.035)
11th	-.080*	-.258***	.094**	-.301***	-.216***	.066
	(.033)	(.066)	(.036)	(.035)	(.040)	(.044)
12th	-.066^{+}	-.422***	.152***	-.328***	-.189***	.047
	(.035)	(.089)	(.038)	(.045)	(.051)	(.051)
Constant	2.225***	2.394***	2.394***	2.206***	2.221***	3.118***
	(.020)	(.047)	(.024)	(.022)	(.029)	(.024)
R^2	.004	.033	.011	.031	.014	.020
Observations	4254	1898	3791	4041	3434	3189

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 3.1: Overall GPA Regressed on Varsity Sports (OLS)

	Full Sample	Female Only	Male Only
Predictor Variable			
Varsity Sports Participation	.089***	.070*	.105***
	(.020)	(.030)	(.027)
Covariates			
Dance/Band Participation	.196***	.197***	.196***
	(.025)	(.029)	(.050)
Year (9th grade= reference)	-.076***	-.061***	-.094***
	(.007)	(.009)	(.010)
10th	-.048***	-.017+	-.083***
	(.008)	(.010)	(.011)
11th	.091***	.127***	.050***
	(.009)	(.012)	(.013)
12th			
Female	.344***		
	(.015)		
Gender/Ethnicity			
Hispanic	-.323***	-.369***	-.280***
	(.023)	(.032)	(.034)
Black	-.432***	-.430***	-.436***
	(.018)	(.024)	(.029)
Asian	.202***	.096*	.300***
	(.030)	(.042)	(.042)
Other	-.089***	-.119***	-.053
	(.024)	(.031)	(.037)
US Born	-.117***	-.162***	-.074
	(.032)	(.043)	(.047)
Parents US Born	.039	.007	.065
	(.030)	(.041)	(.044)
English Spoken at Home	.001	.006	.001
	(.035)	(.049)	(.050)
Mom Age at Birth	.022***	.022***	.022***
	(.002)	(.002)	(.002)
Birthweight (oz.)	.009	.008	.011
	(.006)	(.008)	(.009)
Constant	1.828***	2.244***	1.753***
	(.070)	(.093)	(.101)
R^2	.110	.091	.078
Observations	45218	23912	21306

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 3.2: English GPA Regressed on Varsity Sports (OLS)

	Full Sample	Female Only	Male Only
Predictor Variable			
Varsity Sports Participation	.132***	.103**	.152***
	(.022)	(.032)	(.030)
Covariates			
Dance/Band Participation	.182***	.194***	.152**
	(.027)	(.030)	(.058)
Year (9th grade= reference)			
10th	-.004	.010	-.019
	(.009)	(.013)	(.014)
11th	.012	.038**	-.018
	(.010)	(.014)	(.015)
12th	.109***	.118***	.098***
	(.011)	(.015)	(.016)
Covariates			
Female	.438***		
	(.016)		
Gender/Ethnicity			
Hispanic	-.255***	-.308***	-.206***
	(.025)	(.035)	(.036)
Black	-.388***	-.402***	-.371***
	(.019)	(.025)	(.030)
Asian	.233***	.115*	.344***
	(.033)	(.046)	(.046)
Other	-.111***	-.143***	-.070+
	(.026)	(.035)	(.040)
US Born	-.143***	-.189***	-.098+
	(.035)	(.047)	(.051)
Parents US Born	.036	-.001	.066
	(.032)	(.045)	(.046)
English Spoken at Home	.035	.022	.055
	(.038)	(.053)	(.053)
Mom Age at Birth	.022***	.022***	.023***
	(.002)	(.002)	(.003)
Birthweight (oz.)	.005	.005	.007
	(.006)	(.008)	(.009)
Constant	1.796***	2.355***	1.664***
	(.075)	(.101)	(.109)
R^2	.095	.066	.054
Observations	43570	23085	20485

Note. Standard errors in parentheses
$^{+} p < .10$, $^{*} p < .05$, $^{**} p < .01$, $^{***} p < .001$

Appendix Table 3.3: Foreign Language GPA Regressed on Varsity Sports (OLS)

	Full Sample	Female Only	Male Only
Predictor Variable			
Varsity Sports Participation	.037	.096*	-.010
	(.031)	(.042)	(.045)
Covariates			
Dance/Band Participation	.255***	.198***	.438***
	(.038)	(.044)	(.072)
Year (9th grade= reference)			
10th	-.039*	-.053*	-.019
	(.016)	(.021)	(.026)
11th	-.028	-.014	-.047
	(.019)	(.025)	(.030)
12th	.037	.072*	-.009
	(.025)	(.032)	(.041)
Covariates			
Female	.395***		
	(.022)		
Gender/Ethnicity			
Hispanic	-.268***	-.318***	-.208***
	(.035)	(.047)	(.054)
Black	-.510***	-.495***	-.536***
	(.029)	(.037)	(.048)
Asian	.080^{+}	-.027	.195**
	(.043)	(.058)	(.064)
Other	-.080*	-.095*	-.051
	(.036)	(.046)	(.058)
US Born	-.110*	-.178**	-.024
	(.045)	(.059)	(.071)
Parents US Born	-.016	-.063	.039
	(.044)	(.056)	(.069)
English Spoken at Home	-.075	-.081	-.065
	(.050)	(.064)	(.079)
Mom Age at Birth	.020***	.020***	.021***
	(.002)	(.003)	(.004)
Birthweight (oz.)	.003	.009	-.005
	(.009)	(.011)	(.014)
Constant	2.214***	2.700***	2.112***
	(.106)	(.135)	(.162)
R^2	.078	.058	.052
Observations	20126	11615	8511

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 3.4: Humanities GPA Regressed on Varsity Sports (OLS)

	Full Sample	Female Only	Male Only
Predictor Variable			
Varsity Sports Participation	.144***	.116***	.169***
	(.024)	(.035)	(.032)
Covariates			
Dance/Band Participation	.222***	.241***	.174**
	(.029)	(.033)	(.057)
Year (9^{th} grade= reference)			
10^{th}	-.065***	-.071***	-.058**
	(.012)	(.016)	(.018)
11^{th}	.048***	.083***	.008
	(.012)	(.016)	(.018)
12^{th}	.197***	.235***	.152***
	(.013)	(.017)	(.019)
Covariates			
Female	.298***		
	(.017)		
Gender/Ethnicity			
Hispanic	-.341***	-.381***	-.302***
	(.027)	(.036)	(.039)
Black	-.423***	-.409***	-.442***
	(.021)	(.027)	(.033)
Asian	.189***	.120**	.253***
	(.032)	(.044)	(.047)
Other	-.095***	-.115**	-.073+
	(.027)	(.036)	(.042)
US Born	-.152***	-.179***	-.126*
	(.035)	(.047)	(.052)
Parents US Born	.030	.034	.022
	(.033)	(.045)	(.049)
English Spoken at Home	.039	.015	.065
	(.038)	(.052)	(.055)
Mom Age at Birth	.026***	.026***	.026***
	(.002)	(.002)	(.003)
Birthweight (oz.)	.010	.005	.015
	(.007)	(.009)	(.010)
Constant	1.909***	2.286***	1.830***
	(.080)	(.106)	(.117)
R^2	.085	.078	.064
Observations	38924	20689	18235

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 3.5: Mathematics GPA Regressed on Varsity Sports (OLS)

	Full Sample	Female Only	Male Only
Predictor Variable			
Varsity Sports Participation	.027	-.007	$.054^{+}$
	(.024)	(.037)	(.031)
Covariates			
Dance/Band Participation	$.158^{***}$	$.152^{***}$	$.170^{**}$
	(.032)	(.037)	(.059)
Year (9^{th} grade= reference)			
10^{th}	$-.137^{***}$	$-.126^{***}$	$-.150^{***}$
	(.010)	(.014)	(.015)
11^{th}	$-.166^{***}$	$-.141^{***}$	$-.195^{***}$
	(.012)	(.016)	(.017)
12^{th}	$-.079^{***}$	-.022	$-.142^{***}$
	(.015)	(.020)	(.021)
Covariates			
Female	$.244^{***}$		
	(.017)		
Gender/Ethnicity			
Hispanic	$-.378^{***}$	$-.428^{***}$	$-.333^{***}$
	(.027)	(.038)	(.038)
Black	$-.476^{***}$	$-.486^{***}$	$-.466^{***}$
	(.021)	(.028)	(.032)
Asian	$.200^{***}$	.075	$.316^{***}$
	(.034)	(.049)	(.047)
Other	$-.080^{**}$	$-.115^{**}$	-.035
	(.028)	(.037)	(.041)
US Born	$-.092^{*}$	$-.094^{+}$	$-.094^{+}$
	(.038)	(.053)	(.053)
Parents US Born	$.069^{*}$	.025	$.107^{*}$
	(.035)	(.049)	(.049)
English Spoken at Home	-.024	-.004	-.037
	(.041)	(.058)	(.057)
Mom Age at Birth	$.022^{***}$	$.023^{***}$	$.021^{***}$
	(.002)	(.003)	(.003)
Birthweight (oz.)	$.018^{**}$	$.017^{+}$	$.019^{+}$
	(.007)	(.009)	(.010)
Constant	1.750^{***}	2.008^{***}	1.724^{***}
	(.080)	(.109)	(.116)
R^2	.075	.070	.063
Observations	39841	20970	18871

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 3.6: Science GPA Regressed on Varsity Sports (OLS)

	Full Sample	Female Only	Male Only
Predictor Variable			
Varsity Sports Participation	.051*	.048	.064^{+}
	(.025)	(.037)	(.033)
Covariates			
Dance/Band Participation	.171***	.178***	.154*
	(.031)	(.036)	(.062)
Year (9th grade= reference)			
10th	-.061***	-.036*	-.091***
	(.011)	(.015)	(.016)
11th	-.072***	-.039*	-.110***
	(.013)	(.017)	(.019)
12th	.078***	.120***	.031
	(.016)	(.021)	(.024)
Covariates			
Female	.289***		
	(.018)		
Gender/Ethnicity			
Hispanic	-.371***	-.402***	-.339***
	(.028)	(.039)	(.041)
Black	-.485***	-.443***	-.540***
	(.022)	(.029)	(.035)
Asian	.259***	.178***	.330***
	(.036)	(.050)	(.051)
Other	-.105***	-.122**	-.090*
	(.029)	(.037)	(.044)
US Born	-.108**	-.165***	-.054
	(.038)	(.050)	(.059)
Parents US Born	.026	-.021	.064
	(.036)	(.050)	(.052)
English Spoken at Home	.012	.058	-.024
	(.042)	(.057)	(.061)
Mom Age at Birth	.022***	.020***	.024***
	(.002)	(.003)	(.003)
Birthweight (oz.)	.004	.008	.000
	(.007)	(.009)	(.011)
Constant	1.888***	2.226***	1.838***
	(.083)	(.111)	(.122)
R^2	.084	.070	.074
Observations	35640	18920	16720

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 3.7: Physical Education GPA Regressed on Varsity Sports (OLS)

	Full Sample	Female Only	Male Only
Predictor Variable			
Varsity Sports Participation	.294***	.187***	.358***
	(.023)	(.037)	(.028)
Covariates			
Dance/Band Participation	.452***	.482***	.362***
	(.022)	(.027)	(.038)
Year (9^{th} grade= reference)			
10^{th}	.067***	.094***	.036*
	(.012)	(.017)	(.017)
11^{th}	.050**	.079***	.013
	(.016)	(.023)	(.022)
12^{th}	.094***	.106***	.075**
	(.018)	(.026)	(.024)
Covariates			
Female	-.122***		
	(.018)		
Gender/Ethnicity			
Hispanic	-.418***	-.495***	-.354***
	(.032)	(.046)	(.045)
Black	-.332***	-.445***	-.210***
	(.025)	(.035)	(.035)
Asian	.144***	.086	.197***
	(.037)	(.055)	(.050)
Other	-.091**	-.098*	-.075
	(.033)	(.044)	(.047)
US Born	-.119**	-.158**	-.082
	(.038)	(.053)	(.055)
Parents US Born	.132***	.026	.220***
	(.039)	(.055)	(.054)
English Spoken at Home	.050	.074	.028
	(.043)	(.061)	(.060)
Mom Age at Birth	.015***	.018***	.011***
	(.002)	(.003)	(.003)
Birthweight (oz.)	-.001	-.012	.012
	(.007)	(.010)	(.010)
Constant	2.873***	2.892***	2.762***
	(.087)	(.123)	(.117)
R^2	.079	.098	.065
Observations	26873	13368	13505

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix Table 3.8: Overall GPA (Including PE Grades) Regressed on Varsity Sports

	OLS			Individual Fixed Effects		
	Full Sample	Female Only	Male Only	Full Sample	Female Only	Male Only
Predictor Variable						
Varsity Sports Participation	.144***	.095***	.179***	.041***	.018	.066***
	(.018)	(.028)	(.023)	(.012)	(.017)	(.017)
Covariates						
Dance/Band Participation	.291***	.271***	.341***	.020	-.017	.074
	(.021)	(.024)	(.042)	(.034)	(.042)	(.062)
Year (9th grade= reference)						
10th	-.043***	-.031***	-.057***	-.076***	-.068***	-.083***
	(.006)	(.008)	(.008)	(.013)	(.019)	(.018)
11th	-.033***	-.005	-.066***	-.137***	-.125***	-.148***
	(.007)	(.009)	(.010)	(.015)	(.023)	(.021)
12th	.127***	.167***	.080***	-.017	.049+	-.071**
	(.008)	(.011)	(.012)	(.018)	(.026)	(.024)
Covariates Included?	Yes	Yes	Yes			
Constant	2.031***	2.384***	1.964***	2.582***	2.737***	2.461***
	(.064)	(.087)	(.093)	(.010)	(.016)	(.013)
R^2	.120	.111	.087	.018	.028	.019
Observations	45423	24008	21415	7921	3452	4469

Note. Standard errors in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$
Covariates in OLS not shown include: female, race/ethnicity (black, Hispanic, Asian, other), US Born, Parents born in US, English spoken at home, mother's age a birth, and birthweight

CONCLUSION

As the focus on academic performance has increased in recent years due to national and state policies such as No Child Left Behind and the Common Core State Standards Initiative, time allotted to physical activity opportunities in schools via recess and physical education have been reduced to promote more instruction time for subjects such as mathematics and language arts (Centers for Disease Control and Prevention, 2010; Institute of Medicine, 2013). The reduction in adolescent physical activity in school by policy makers and administrators is perhaps influenced by James S. Coleman's classic work "The Adolescent Society" (1961) where he hypothesized that if time was taken from academic programs to allow other pursuits, academic performance would suffer in a zero-sum model. However, academic performance is not purely a function of academic programs and these "other" pursuits, such as physical activity, may have positive impacts on educational outcomes.

Various reviews of observational and experimental studies report a positive or null relationship between physical activity and educational outcomes and little to no published evidence of negative relationships (Centers for Disease Control and Prevention, 2010; Fedewa & Ahn, 2011; Hattie & Clinton, 2012; Howie & Pate, 2012; Strong et al., 2005; Trudeau & Shephard, 2008). Increases in physical activity have also been linked to benefits in cognition and behaviors that are related to academic performance (Strong et al., 2005; Tomporowski, 2003). As most US adolescents spend the majority of their waking hours in schools, a potential consequence of increased instruction time in curricular subjects is a decrease in daily physical activity, which may have adverse impacts on education.

Most research in this area is correlational in nature and the experimental or quasi-experimental research that make causal claims has primarily consisted of smaller experiments or focused on to short-term educational outcomes such as academic performance (e.g., grades, tests, etc.). Furthermore, these studies have primarily focused on these relationships for children and not for adolescents.

This dissertation fills this void in research by exploring the impact of additional adolescent physical activity on educational outcomes using a nationally representative sample of adolescents and advanced statistical methods. In particular, the first and second studies use instrumental variables to estimate the causal relations that typically cannot be done through using a simple OLS regression using survey data.

In a typical OLS regression using survey data, researchers are unable to make causal inferences because of three potential issues. In the case of this dissertation where the first two studies examine the impact of different measures of physical activity on schooling outcomes, the first issue is directionality; researchers are unable to conclude if physical activity have an impact on schooling outcomes or if schooling outcomes has an impact on physical activity. This issue, however, can be resolved through the use of longitudinal data in this dissertation. The second issue is potential misreporting of physical activity by the respondents of the survey, which can potentially bias estimates. For example, adolescents who do not partake in physical activity may over-report their physical activity and this may lead to imprecise estimates. The last issue is the exclusion of potential unobservable "third" factors related to physical activity that can bias the relationship between physical activity and the schooling attainment in the analytic models. Any one or combination of these issues can create a biased estimate of the factor of interest, which can bias the relationship between physical activity or physical education classes and the schooling outcome in the analytic models and prevent causal estimates.

Instrumental variables, however, can be used to account for these issues in survey data to produce causal estimates using a two-stage procedure. The first involves using variation outside of a respondent's control, such as state or neighborhood resources, laws, and policies, to calculate an unbiased predicted estimate of the factor of interest using an OLS regression. The second stage involves using this predicted value from the first stage to estimate the causal relationship between the factor and outcome of interest.

In addition to instrumental variables, this dissertation also uses individual fixed effects adjustments in the third study. Essentially, this study takes advantage of transcript data to compare grades earned in years in which a student did and did not participate in varsity sports. By comparing one observation to another observation of the same student at a different point in time, all observable and unobservable time-invariant individual factors that can bias the relations between the factors and outcome of interest, such as gender, race, and general background, are accounted for. This provides a conservative estimate of the relationship between a varsity sports participation and academic performance (i.e. grades) relative to typical estimates in a simple OLS regression model using survey data that do not make adjustments for unobservable factors that can bias the relationship between a factor and outcome of interest.

The first study provides novel estimates of the impact of additional physical activity per week on educational attainment using instrumental variables. Significant findings from this study may provide a basis for policy-makers to imagine different potential policy-relevant solutions or levers that can increase adolescent physical activity. Results from the first study suggest that a standard deviation increase in physical activity (i.e., 4.27 times per week) increases years of completed schooling by 1.54 years (standard error = .64 years). When considering the impact of one additional instance of physical activity per week, an additional instance of physical activity increases years of completed schooling by .36 years. Moreover, about a third of this relationship is mediated by improvements in cognition. Increases in adolescent weekly physical activity can provide a means to improve educational attainment and future research should examine policy-relevant ways of increasing physical activity as a means to improve education.

These large estimates are robust to a number of different internal validation assessments, including different instrumental variable specifications, different conditions in the first stage of the instrumental variable analysis, and falsification tests. As there are no experimental or quasi-experimental studies that estimate the impact of adolescent physical activity on educational attainment, the estimates can be compared to experimental studies that examine the impact of physical activity on academic performance in children. The results for this study (β = .69) fall within the range of true-experimental design studies [.00-1.49] used by Sibley and Etnier (2003) in their review of small experimental studies examining the link between physical activity and cognition or academic performance in children. The range in effect sizes may be attributed to the intensity and duration of physical activity the experimental studies in different meta-analyses ranged in intensity from 5 minutes of exercise to 90 minutes of physical activity per week and ranged in duration from 20 days to the academic year. Although the estimates using instrumental variables in the first stage may seem large, they are comparable to experimental studies linking physical activity and educational performance in children.

The second study extends the findings from the first study to explore physical education classes as a policy lever to increase adolescent physical activity. Increasing physical education presents a potentially viable lever for policy makers as some states require students to attend physical education classes to graduate from high school. High schools also often have access to locations where adolescents can hold their physical education classes, such as school gymnasiums or fields. Furthermore, physical education participation has been decreasing over the past few decades and finding ways to increase physical education would not a radical change to the education system—it would simply be reverting participation levels to those in previous years which have historically been shown to be sustainable and would not constitute a fundamental change to a school's infrastructure. Results using instrumental variables show an additional hour of weekly PE predicts an increase in years of completed schooling by .35 years (standard error = .15 years). In line with the results from the first study, increased participation in physical education classes provide a means to improve educational outcomes.

As there are no experimental or quasi-experimental studies that estimate the impact of an additional hour of weekly physical education classes in adolescence on educational attainment, a potential means of validating the results of this study is to compare the effect size of this study (β = .19) with studies focused around physical activity and educational achievement in children. In a meta-analysis of 59 studies focused around physical activity and education in children from 1947 to 2009, Fedewa and Ahn (2011) found the average effect size to be .16 standard deviations in studies with physical activity interventions that occurred once a week. In physical activity interventions that occurred twice a week, the average effect size was reported as .27 standard deviations. Additionally, in a 2-year experimental study examining the benefits of physical activity on academic performance where the treatment groups were given an additional hour and half of physical education classes relative to the control group, the treatment groups scored higher on a standardized achievement test on a battery of English assessments with average effect size of .17 (Sallis et al., 1999). The estimates using instrumental variables in the second study may seem large but are practically identical to those linking physical education and educational performance.

Similarly to the second study, the third study explores another potential policy lever that can be used to increase adolescent physical activity—varsity sports participation. Finding ways to increase varsity sports participation presents another viable means for policy makers as many schools already offer varsity sports in certain but not all popular sports. Increased funding for varsity sports can increased the number of offered sports in a given school, which can increase participation in varsity sports and subsequently, physical activity. Furthermore, varsity sports can be used as a substitute for the physical education high school graduation requirement in many schools. Unlike the first two studies of this dissertation, this study examines the relationship between increased physical activity and short-term educational performance outcomes such as grades in classes such as mathematics, science, and English as a means to better understand the impacts of physical activity on education on the whole. Furthermore, educational performance can be considered a mediating mechanism in the relationship between physical activity and educational attainment.

Participating in varsity sports was significantly associated with a .089 (3.7%) increase in overall GPA and the association was greater for males (.105 or 4.7%) than for females (.070 or 2.7%) using an OLS regression. However, in the presence of individual FE adjustments, there was no association between varsity sports participation and overall GPA, even when the samples were examined by gender. When considering the associations between varsity sports participation and grades in different classes, the results suggest that it may be possible for low-performing adolescents who are skilled at sports to receive slight unjustified boosts in their grades to meet their school's minimum GPA requirement for varsity sports participation in classes where the teachers may also be employed as the coach of a varsity sports team. The magnitude of the results found in the third study are similar to those found by Lipscomb (2007) who also used a fixed effects strategy to test whether sports participation provides an immediate return to student learning and found participation in sports to be associated with a 2% percent increase in math and science scores.

Taken together, these three studies find increasing adolescent physical activity to be a potential means in improving educational outcomes for adolescents. Increases in physical activity can be accomplished through educational policy levers in schools where adolescents spend most of their waking hours. These increases can improve both short term academic performance (evidenced by sports on achievement) and may persist past high school (evidenced by attainment outcomes).

Although it may be important to increase physical activity in all stages of human development, adolescence may be a particularly important developmental stage for physical activity. Findings from the first study show that a significant amount of the relationship between physical activity and educational attainment can be explained through improvements in cognition. Along those lines, adolescence may be particularly important as one important component of puberty entails significant brain development. Changes in physical activity may promote increased or additional brain development and cognition, which has been linked to academic performance and achievement.

Furthermore, finding ways to increase adolescent physical activity can lead to changes in health-related behaviors. Improved health behaviors in adolescence may persist (e.g., amount of exercise, recreational sports, etc.) into adulthood and the fadeout of these behaviors may be significantly less relative to academic interventions.

Future Directions

This dissertation presents a promising first step into a potentially profitable line of research. There are a number of additional mediational pathways between physical activity and education that have yet to be explored. Potential mediators include improvements in time-management, ability to focus, and social skills, among others. The differential associations of sports on educational performance by gender also warrant future research on factors that can moderate the relationship between physical activity and education. In addition to gender, other potential mediators include socioeconomic status, race/ethnicity, and weight status (i.e., healthy, overweight, obese), among others.

Another interesting research question would to be identify for whom potential physical activity focused policy changes would be relevant. An important strength of instrumental variables is that it provides unbiased or causal estimates. Although instrumental variables were used to estimate an unbiased or causal estimate of weekly physical activity and weekly hours of physical education classes on eventual educational attainment in study 1 and 2, respectively, this estimate is only applicable for a certain proportion of adolescents. When considering potential policy levers that can increase adolescent physical activity, there is a significant issue with "noncompliance" or the populations of adolescents who would not be affected by changes in policy. There may be adolescents who are already participating in physical activity and changes in policy to increase physical activity would be irrelevant to them. Similarly, there are adolescents who will find ways to not partake in physical activity regardless of any changes in policy.

Essentially, the results from the first and second study are not applicable to the whole population of adolescents—they are only applicable to adolescents do not participate in physical activity but would participate in physical activity only if they were affected by a policy lever intended. The impact of physical activity on educational outcomes is unknown for anyone outside of this group and future research should seek to find ways to identify who these adolescents are and what percent of the adolescent population are composed of these adolescents.

It would also be profitable for researchers to find policy changes that increase or decrease the amount of adolescent physical activity as a means to replicate and potentially validate the findings from this study. Potential policy changes include cuts in school district level funding for sports activities or evaluating the impact of large-scale donations given to schools earmarked for increasing physical education time or increasing participation in varsity sports. School district or state decisions to change physical education requirements in schools may also prove to be an interesting way to estimate the impact of physical activity on education.

This dissertation is focused on adolescence but it would also be interesting to examine the long-term impacts of physical activity in other age groups. One interesting population to study would be young adulthood or collegiate athletes. Since many adolescents consider sports a means of attending college and participation in college sports is governed by the National Collegiate Athletics Association (NCAA), it would be particularly interesting to examine the relationship between playing a collegiate sport and various educational outcomes.

A potential criticism of the studies in this dissertation is that the measures used for physical activity are primarily based on self-reports. Future research should seek to replicate and extend these studies using a more accurate measure of physical activity, such as commercially available fitness trackers.

It would also be valuable to use brain scans to validate the findings that cognition mediates the relationship between physical activity and educational attainment. Neuroimaging studies have shown differences in brain structure to be attributed to differences in physical activity for adults (Colcombe et al., 2006; Hillman et al., 2008; Kramer & Erickson, 2007; Pereira et al., 2007) and it would be interesting to see the extent to which this would also apply for adolescents whose brains are developing during puberty.

Suggestions for Policy Makers

The findings from this dissertation hint at the potential academic harm that decreasing physical activity can have on adolescents, especially in light of the recent trends in decreasing physical activity in schools. If schools elect to introduce additional curricular time in math and English language arts in school at the expense of opportunities for physical activity (i.e., physical education classes), the academic benefits of this additional curricular time should be considered relative to the academic benefits of physical activity.

Furthermore, although the studies in this dissertation focus on the educational benefits of physical activity, there are a number of health benefits of increased physical activity (Centers for Disease Control and Prevention, 2010; Currie et al., 2010; Warburton et al., 2006). Policies to increase adolescent physical activity can hit two (and potentially more) problematic areas in the US at once—obesity and education.

However, given that these findings are novel and an unexplored area of research, policy makers may want to exercise some caution before considering initiatives to increase or decrease physical activity in schools until the findings are validated by additional research. Among others, policy makers may have to trade time devoted to curricular classes in order to increase physical activity in schools. Assuming an adolescent spends six hours per school day in high school in curricular classes such as mathematics and English without any time devoted to physical education classes, an hour of physical education classes per school day would require the amount of time devoted to curricular classes to be typically taught across six hours to be taught in five hours. Although decreasing time to curricular subjects may improve the efficiency of teaching as teachers would have to teach the same amount of material in a shorter amount of time (Trudeau & Shephard, 2008), decreasing time for curricular classes may also have an negative impact on high school grades, which has been shown to be predictive of academic performance in college (Hoffman & Lowitzki, 2005; Zwick & Sklar, 2005). Policy makers should weigh the potential payoffs of increased physical activity with the consequences of decreased curricular time. In the meanwhile, policy makers may consider supporting additional funding on research focused around the educational benefits of adolescent physical activity.

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