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Physical activity levels of urban and rural young children in the Iowa Bone Development Study

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PHYSICAL ACTIVITY LEVELS OF URBAN AND RURAL YOUNG CHILDREN IN THE IOWA BONE DEVELOPMENT STUDY

by

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

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ABSTRACT

A better understanding of the association of the environment to young children's physical activity is needed to design effective behavioral interventions and to improve communities' infrastructures in ways that support the development of healthy behaviors.

This thesis used data from the Iowa Bone Development Study (IBDS) to examine activity behaviors of young children in urban and rural Iowa. Mean daily minutes of moderate through vigorous physical activity (MVPA) and vigorous physical activity (VPA), as recorded by accelerometry-based physical activity monitoring in the IBDS, were compared by level of socioeconomic status (SES) and census block type (urban or rural). Media use (television and videogames), in hours per day by parental report, was similarly compared. Logistic regression was used to assess the association of census block type (urban or rural) with lower categories of MVPA and VPA, and with a high category of media use (exceeding the American Academy of Pediatrics (AAP) recommendation for ≤ 2 hours/day of media).

Mean age of the 400 participants included in this thesis was 5.65 years (SD = 0.53), females comprised 53.5%. Children's mean daily minutes of MVPA and VPA were not significantly different among SES levels nor between urban and rural census blocks. Rural children had decreased odds for lower categories of MVPA (Boys' OR 0.91; 95% CI: 0.51, 1.60) (Girls' OR 0.89; 95% CI: 0.53, 1.50) and VPA (Boys' OR 0.84; 95% CI: 0.48, 1.48) (Girls' OR 0.90; 95% CI: 0.54, 1.52), but not significantly so.

Lower SES boys and girls engaged in more daily media use (hours/day) than higher SES children, and a higher proportion of low SES children exceeded the AAP recommendation than did middle-level or high SES children. Rural boys' media use (2.7 hours/day) was higher than that of urban boys (2.3 hours/day) (95% CI: 0.06, 0.80 hours/day), whereas urban and rural girls' media hours/day were not significantly different. Odds for excess media use were higher for rural boys (OR 2.11; 95% CI: 1.14,

3.11) and for low SES boys (OR 2.99; 95% CI: 1.34 6.68), as well as for low SES girls (OR 4.12; 95% CI: 1.95, 8.71).

Although rural and urban children's MVPA and VPA did not differ in this thesis, rural and low SES boys had both higher daily media hours and increased odds for exceeding AAP media recommendations. Odds for excess media also were increased for low SES girls. Interventions to improve healthy behaviors of young children by limiting screen-based recreation and/or supplying means for alternate activity and play opportunities may be especially beneficial when focused on lower SES and rural areas.

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CHAPTER I

SPECIFIC AIMS

To explore the physical activity levels of children participating in the Iowa Bone Development Study (IBDS) by type of residential environment, existing data from the (IBDS) are supplemented with U.S. Census data and analyzed. This thesis addresses the following specific aims:

1. To describe the distribution of study participants' socioeconomic status (SES) by population attributes of the place of residence using the urban versus rural designation of the census block of residence.
2. To describe and compare the distributions of study participants' levels of moderate through vigorous physical activity (MVPA), vigorous physical activity (VPA), and screen-based media (television and videogame) use by levels of socioeconomic status (SES).
3. To describe and compare levels of MVPA, VPA, and media use of participants living in urban and rural census blocks.
4. To estimate through logistic regression modeling the odds for lower levels of physical activity and for high media use, given the residential environmental context of urban versus rural census blocks.

CHAPTER II

BACKGROUND

Physical Inactivity, Risk Factor and Economic Burden

There is a growing national and international interest in the recognized link between physical activity and health. Physical inactivity has long been known to be a major risk factor for a vast array of health problems.[1-3] Hundreds of studies have provided evidence of association between physical inactivity and common diseases, including obesity, hypertension, type 2 diabetes, colon cancer, osteoarthritis, osteoporosis, and cardiovascular disease (CVD).[3] Moreover, sedentary living has been said to contribute to as many as 10 percent of all deaths in the U.S. and 25 percent of all deaths from chronic disease.[3]

In the United States, health spending has increased from 8.8 percent of Gross Domestic Product in 1980 to a projected 17.6 percent in 2009,[4, 5] and shows little sign of being brought under control despite decades of public awareness and scrutiny of the problem. Given the difficulty of curbing the costs of treating diseases, the potentially cost-effective strategy of preventing disease is more important than ever. Among the commonly identified approaches to healthy living, increasing physical activity is seemingly quite amenable to widespread adoption in the population, requiring simple lifestyle changes. Although individuals can introduce some measure of increased physical activity into their current lives without incurring substantial financial consequences, long-term environmental changes in community structure to provide inducements to physical activity will require social resources.[3]

Pediatric Moderate-Through-Vigorous Physical Activity Recommendations

The Healthy People 2010 (HP2010) objectives recommend that U.S. children accrue 30 minutes or more of physical activity at an intensity of three or more metabolic equivalents (METs) on at least five days per week.[6] The 2008 Physical Activity Guidelines for Americans, issued by the U.S. Department of Health and Human Services, recommend that children and adolescents perform 60 minutes or more of physical activity daily, mostly moderate- or vigorous-intensity aerobic activity.[7] The National Association for Sport and Physical Education (NASPE) issued guidelines in 2004 to include: Children should accumulate at least 60 minutes, and up to several hours, of age-appropriate physical activity on most if not all days of the week. This daily accumulation should include moderate and vigorous physical activity with the majority of the time being spent in activity that is intermittent in nature.[8] Other similar guidelines have been issued, including the President's Council on Physical Fitness and Sports and the United Kingdom (UK) Expert Consensus Group Guideline.[9, 10] These guidelines, particularly HP2010 with fewer minutes of recommended daily MVPA, may not allow the identification of children active enough to achieve health benefits versus those who are not. In previous studies, most young children met and exceeded 30-60 minute guidelines for MVPA.[11, 12] The HP2010 guidelines did not reveal age-related trends and have shortcomings as guidelines for physical activity in youth.[11]

Pediatric Vigorous Physical Activity Recommendations

The HP2010 objectives recommend children accrue at least 20 continuous minutes of physical activity at an intensity of six or more METs on at least three days per week whereas the American Heart Association recommends at least 30 minutes of VPA on three or four days per week.[6, 13] The unique activity patterns of young children – numerous bursts of activity lasting seconds, interspersed with periods of recovery – may be inconsistent with recommendations.[14] Sustained bouts of VPA are a form of activity more characteristic of adults and may be an inappropriate recommendation for children.[11] The 2008 U.S. Federal guidelines advise that vigorous activity be accomplished at least 3 days per week, without specifying whether sustained episodes are recommended.[7]

Pediatric Inactivity as a Risk Factor for Adult Inactivity

Physically inactive children have the potential to become disproportionate consumers of health care resources.[15-18] Many tracking studies have suggested a significant, although low, prediction that physically inactive children and youth will become inactive adults, and inactivity in adulthood has been irrefutably linked to poor health and increased medical expenditures.[18-21] Telama et al. stated that, "childhood is usually considered to be the best age for socialization into physical activity, and attitudes and skills acquired in childhood are regarded as important also for habitual physical activity in adulthood."[22] In a study of Finnish children ages 9 (n=610), 12 (n=624), 15 (n=572) and 18 (n=503), low but statistically significant correlations (except for the 9-year-old girls, whose correlation was zero) were found between physical activity obtained by questionnaire at baseline and at 9 and 12 years' follow-up (1980, 1989, and 1992). Competitive sport participation and physical education grade were the best predictors of physical activity behavior 9 and 12 years later.[22]

In follow-up at age 36 of a 1946 birth cohort in England, Scotland, and Wales (n=3300), several childhood attributes, including sports skills in school, high energy level and extroverted personality, predicted higher rates of participation in self-reported adult sports and recreational activities.[19] These findings highlight the importance of developing healthy habits in childhood.

Janz and colleagues found that fitness (assessed by muscular and aerobic fitness testing) and physical activity (assessed by questionnaire) demonstrated a moderate to high degree of tracking throughout a 5-year annual follow-up from childhood (baseline ages 7-12) to adolescence (ages 12-17) of 126 subjects in the Muscatine (Iowa) study.[20]

Pediatric Inactivity as a Long-term Health Risk Factor

Because inactivity during childhood could lead to an increased risk in adulthood of lifestyle diseases such as CVD and diabetes,[3, 15, 22] prevention of chronic disease rightfully begins in childhood.[18, 23, 24] In addition, physical activity has immediate benefits in youth; health outcomes such as lower adiposity levels, lower blood pressure levels, higher levels of bone mineral content, and improved psychological health have been associated with childhood physical activity.[25-27]

Obesity is closely related to increased childhood risk of CVD, some forms of cancer, and psychosocial problems.[3, 16, 21] Pediatric obesity has been associated with sedentary behavior.[21, 28-31] The relationship between obesity and lifestyle factors reflects a balance between energy consumption and expenditure, and physical activity is the most malleable form of energy expenditure among adults and children.[21] A recent increase in obesity prevalence in children has been plausibly linked to cultural changes accompanying societal development, such as greater availability of food and fewer required physical activities.[23, 32, 33] In U.S. preschool-aged children (2-5 years), prevalence of obesity increased from 5.0% in the 1976-1980 NHANES (National Health and Nutrition Examination Survey) to 12.4% in the 2003-2006 survey.[34] The number of overweight U.S. children and adolescents increased by 100% between 1980 and 1994, a period during which there were no material changes in the U.S. population's gene pool.[35] Thus, environmental effects on energy balance are likely to account for the increased prevalence of overweight and obesity.

Children's Media Use and Risk for Overweight

It has become common in academia, in lay reporting, and in the public's mind, to place blame for the childhood obesity epidemic at least partly on increased time spent watching television and playing video games. Sedentary behavior, particularly television-watching, not only reduces energy expenditure by displacing some forms of physical activity, but also affects the balance on the side of energy consumption. A 2002 review by Ebbeling et al. summarized cross-sectional studies of pre-adolescent children in the U.S., England, and Mexico that saw associations between television-watching and children's unhealthful food choices and higher calorie consumption.[32] A cross-sectional study surveyed 240 parents of children aged 2-5.9 years and found positive associations between children's television-watching and meals eaten at fast food restaurants.[36] Although a single marker of inactivity is unlikely to fully explain a relationship between sedentary behavior and obesity,[37] data have suggested a dose-dependent relationship between the duration and frequency of media use and risk of childhood overweight. A 1999-2000 survey of 2,761 parents of U.S. children between the ages of 1 and 5 years assessed the television-viewing behaviors of children; children's body mass index (BMI), as calculated using height and weight data extracted from clinical charts, was positively associated with television-watching.[38] The American Academy of Pediatrics recommends that parents limit children's total media time to not more than 2 hours daily, remove television sets from children's bedrooms, and discourage children less than 2 years old from watching television.[39]

Correlates of Pediatric Physical Activity

James F. Sallis, PhD, a prolific contributor to the physical activity literature, along with his co-authors, has suggested that the term "correlate" be used with respect to factors shown to be statistically significantly associated with types and amounts of physical activity in cross-sectional studies; the familiar term "determinant," which has been used too broadly, should be more selectively employed to describe only possibly causal factors as evidenced by longitudinal or controlled studies.[40, 41] This thesis has heeded these recommendations.

Correlates of physical activity need to be better understood in order to develop more effective interventions for promoting healthy behaviors among children. Identifying correlates does not necessarily identify causal inferences, but remains useful in generating hypotheses for further study.[25, 42] The correlates are thought to be multifactorial, and include:

a. demographic factors including age, ethnicity, socioeconomic status;
b. biological factors including body mass index, parent overweight/obesity;
c. psychological factors including self-esteem, perceived competence, body image, self efficacy;
d. behavioral factors including healthy diet, caloric intake, previous physical activity, sedentary time;
e. socio-cultural factors including parental physical activity, parental physical activity participation with youth, parent-perceived benefits and barriers to physical activity, parental encouragement;
f. physical environmental factors including access to facilities/programs, season, milieu (such as rural/urban), neighborhood safety.

Significant associations have been identified between childhood physical activity and many of these factors, reinforcing the notion that physical activity behaviors likely involve a multitude of influences.[3, 25] The relationships of environmental factors to physical activity are poorly understood, and yet they may be the most important.

Environmental Correlates of Pediatric Physical Activity

Health-related behaviors can be affected by physical aspects of the living environment inasmuch as those aspects can act as barriers to or facilitators of physical activity.[43-45] Early research exploring correlates of children's physical activity mainly concerned psychological factors.[46] Broader socio-cultural and ecological influences received less attention until the 1990's.[47] Individuals' behaviors have important consequences for overall energy expenditure, and environmental contexts can promote or discourage a range of behaviors.[43, 45, 48] Ecologic models of behavior include physical and social environments as determinants of health, and are more inclusive than models of behavior based upon factors related to the individual alone.[49, 50]

A decision to choose active behavior over sedentary behavior is based not only on motivation or personal preference, but also on access to and availability of active or sedentary alternatives in the environment. In behavioral economic research experiments involving small groups of children aged 8-12 years (United States, 1991), Epstein et al. observed increased physical activity following environmental changes that increased the proximity and convenience of physical activity while creating unfavorable access to sedentary activities.[28] An increasingly obesogenic environment, increasing access and availability of unhealthful foods and physical inactivity, has been largely blamed for the increase in childhood and adolescent obesity.[51-53]

Variation in physical activity and in fitness between urban and rural children has been detected in previous studies. In a 1985-86 survey of 3270 Icelandic schoolchildren ages 11-16, urban students were more physically active and less sedentary during leisure time than rural students. Differences in the activity levels of rural and urban children were more apparent during leisure time than during school time, implying that efforts to improve physical education in public schools may not translate into increased voluntary activity in leisure time.[54] Physical fitness was tested in cluster samples of European school classes in the 1970's under the auspices of the World Health Organization. Urban children were fitter than children living in sparsely populated areas of Norway (ages 8-14), Iceland (ages 8-14), West Germany (ages 12-18) and Czechoslovakia (ages 12-18).[55] These data appeared to refute a widespread concept that urbanization adversely affects exercise and fitness during growth; perhaps the urbanized society stimulated children to vigorous play and sport as compared to their relatively socially isolated counterparts in the rural environment.[55] In North Carolina, McMurray and colleagues did not see a difference between rural (n=1151) and urban (n=962) third- and fourth-graders' activity assessed via questionnaire at baseline (1996) in the Cardiovascular Health in Children

Study; although activity levels did not differ, rural children were less fit and at increased risk for obesity, as defined by skinfold measurements and body mass index (BMI).[56] In Sallis, Prochaska and Taylor's 2000 review of European studies, two studies had found rural children, 4-12 years of age, less likely to be physically active than urban children; but the reverse was found in two other studies.[25] The association of rural versus urban environment with children's physical activity has been indeterminate.

These studies have utilized different methodologies in defining urban and rural areas. Consequently, it is not always clear whether the characterizations of European residential areas as urban or rural are comparable to those in the United States. European studies of children's physical activity often described participants as living in rural areas or in cities, without providing operational definitions of the terms.[25, 54, 55, 57-59] In a Swedish study reviewed by Sallis et al., categorization was based solely on the total population of municipalities.[25, 59] The North Carolina study by McMurray et al. used the metropolitan or nonmetropolitan designation of U.S. counties in defining whether a school was located in an urban or rural area,[56] but definitions in U.S. studies can also vary widely.[60]

Studies cited often included children older than 6 years of age, and school attendance was likely to have affected physical activity habits. There are fewer studies comparing physical activity patterns and correlates of rural and urban younger children.[3, 30] Describing physical activity correlates related to the residential surroundings of young children could shed light on behavioral patterns that develop prior to the influence of school attendance.

Ecologic Policy and Inactivity

With the Active Community Environments (ACES) Initiative, the U.S. Centers for Disease Control and Prevention (CDC) promotes the concept of enhancing activity by modifying the physical environment, with the understanding that a communities' characteristics play a significant role in promoting or discouraging physical activity.[61] Physical activity initiatives seem particularly well-suited to ecologic models, but more research is needed to refine assumptions about the environment and physical activity.[3, 62] Although data are less conclusive for children, studies showing associations between adults' physical activity and neighborhood characteristics or urban form are common in both the health and transportation literature.[61-66] In particular, walking has been positively associated with population density and mixed-use zoning.[62-64, 67, 68] An ecologic study of urban sprawl and adult physical activity found urban form significantly associated with some forms of physical activity and with some health outcomes.[49] Safety, aesthetics, population density and mixed-use zoning have been identified as modifiable factors correlated with recreational and transport walking and bicycling in adult populations.[67] The association of children's leisure activity with community form is less apparent.

Public health officials and healthcare providers in Iowa and elsewhere in the U.S. wish to identify the correlates of activity and provide interventions to improve children's activity levels.[25, 69, 70] The current epidemic of childhood obesity, for example, would best be addressed via preventive efforts, with interventions targeting young children.[47] Patterns of childhood physical activity can lay the foundation for lifetime patterns of physical activity. Beyond physical benefits such as body weight regulation, habitual physical activity also provides other benefits, including psychological and social well-being.[19, 23, 47]

Identifying the environmental correlates of physical activity and inactivity will inform more comprehensive intervention strategies for increasing physical activity and decreasing inactivity among children. The most modifiable aspects of physical activity are best targeted for public health interventions.[43] There is an urgent need to better understand modifiable environmental factors and how they might act to affect physical activity behaviors.[3, 43] Repairing the environment requires an understanding of factors that affect physical activity patterns.

Urban and Rural Community Form as Correlates

Understanding environmental correlates of physical activity is essential to identifying determinants and developing interventions. A combination of environmental factors and individual differences (preferences) affects children's choices between active and sedentary behavior.[28, 50, 71] Interventions could have a broader impact on activity levels when applied at the environmental level (access and availability) rather than directed at individuals' behaviors. Moreover, even with effective behavioral interventions, the opportunity to make progressive changes may be constrained by environmental factors that remain non-conducive to physical activity. As stated by King et al., "intrapersonal, interpersonal, physical environmental and socio-cultural variables function interactively to promote or hinder individuals' engagement in physical activity."[72]

The characteristics of a particular residential area, such as its traffic patterns, proximity of recreational facilities, and population density, are relatively stable and long-term in their influence on choices of behavior. Public health and urban planning research lends support to the notion that community form impacts residents' health and health-related behaviors.[3, 33, 44, 45, 48, 49] The more recreational settings and facilities that are incorporated into a community, the more likely its residents are to regularly engage in physical activities.[72] Further investigation of this notion is needed to enable public health researchers to assess the importance of including such environmental characteristics in analyses of physical activity and health behaviors.

Adult participants in the Third National Health and Nutrition Examination Survey (NHANES, 1988-1994) who lived in urban and suburban homes built before 1946 (a proxy for older neighborhoods) were more likely to walk long distances frequently than adults living in homes built after 1973.[62] Likewise, there could be infrastructural differences in the community environment, such as recreational facilities and organized sports programs, that affect the access and availability of children's physical activity opportunities. In addition to influences exerted at the community level, correlates at the micro-level of neighborhood structure and home environment, such as proximity to play spaces or playmates, could bear on children's day-to-day activity choices.

Although it is tempting to speculate about which components of community form may best predict levels of children's physical activity and inactivity, there are neither clear data nor *a priori* reasons that would warrant assuming any particular relationship. There are studies comparing rural and urban adults' levels of walking and bicycling for transportation and for leisure;[49, 61, 65] however, few data establish whether urban or rural young children are more physically active.[25] It was for this reason that this thesis was designed to explore the association of urban and rural living environment to the activity behaviors of young children participating in the Iowa Bone Development Study.

Monitoring of Pediatric Physical Activity

Various techniques of measuring physical activity in children and adolescents carry differing strengths and weaknesses. The reliability and validity of accelerometry-based physical activity monitoring has been studied, as has its appropriateness for measuring the quantity and intensity of physical activity.[73-75] Kohl and colleagues have recommended, in a review of various means of assessing children's and adolescents' physical activity (ages 4-17 years), that detecting and assessing patterns of physical activity over an extended period is best accomplished with electronic monitoring, which includes accelerometry-based physical activity monitors (PAMs).[76]

The PAM can be used to provide a continuous recording of minute-by-minute movement counts via its integrated circuitry and memory. The device is designed to monitor physical activity in non-controlled settings without interfering with movement. A vertical-axis piezoelectric bender element embedded in the monitor generates a signal proportional to the force acting on it as it bends with movement while it is worn during physical activity. A minute-by-minute record of movement can be generated and stored in memory over a period of days or weeks.[75, 77] The Model No. 7164 uniaxial accelerometry-based PAM used in the IBDS was once sold by Computer Science Associates, Inc. (CSA) of Shalimar, FL. Manufacturing Technology Incorporated (MTI) of Fort Walton Beach, FL purchased CSA and later became ActiGraph LLC (Pensacola, FL). The Model 7164 instrument is referred to as the CSA/MTI/ActiGraph, but will be called simply ActiGraph in this thesis.[78]

In a calibration study, data from accelerometry-based physical activity monitors were used to estimate intensity of physical activity in children. Monitoring of minute-by-minute respiratory gas exchange measures was used to determine actual METS while children ages 6-17 years wore a PAM during treadmill sessions of four to five minutes. The PAM counts were used in a regression equation with no significant difference shown between actual and predicted METS.[79]

The ActiGraph PAM showed satisfactory validity and reliability in studies by Janz and colleagues.[75, 77] In a 1994 paper, Janz et al. reported the ActiGraph PAM valid and useful for measuring children's activity in field settings. Thirty-one children and adolescents, ages 7-15 years, concurrently wore both an ActiGraph PAM and a heart rate telemetry monitor. There was moderate to high concurrent validity for the ActiGraph PAM and the criterion measure, heart rate telemetry, for each monitored day ($r = 0.50$-0.74). The low-to-moderate between-day stability of individual measures ($r = -0.23$ to 0.53) indicated that more than 3 days of monitoring was preferred to assess usual activity.[75] In a follow-up study, 4 or more days of monitoring achieved intraclass correlation coefficients (a reliability measure) indicative of stability (R=0.75-0.78, CI=0.60-0.88) for children and adolescents (ages 7-15 years).[77]

Why an Exploratory Study?

Although correlates cannot be assumed to be causal factors, research to identify them can be useful in generating hypotheses and posing possible causal relationships between physical activity and factors that can be targeted with intervention.[40, 68] Research on social environmental variables (e.g., social support) has consistently identified associations with physical activity, building a foundation to progress into examining causal pathways.[67] It is premature to attribute physical activity causal effects to specific physical environment variables.[67]

The results of this thesis will facilitate the generation of testable hypotheses concerning specific environmental factors most directly related to physical activity levels. Indeed, if the urban or rural environment is found to be associated with physical activity behaviors, additional explanatory studies will be needed to quantify which correlates of the urban or rural environment were contributory. Understanding the association, if any, of urban form with physical activity levels would be useful at the state and community levels to plan new development or improve existing communities in a manner most conducive to healthy living. Investigation of urban and rural community forms and the residents' physical activity can provide the opportunity to optimize interventions by taking into account differences in residential environments.[80]

This thesis will investigate whether physical activity behaviors of children participating in the IBDS are associated with rural or urban designation of the address of residence. This question is significant because, according to the Census Bureau, about 40% of Iowa's 3 million residents live in rural areas.[81] Analyses will be carried out at the census-block level to explore the possible association of neighborhood characteristics with children's activity choices.

CHAPTER III

METHODS

The Iowa Bone Development Study

This thesis involves secondary analysis of data originally obtained via the Iowa Bone Development Study (IBDS), an offshoot of a longitudinal study of fluoride exposures, dental caries and dental fluorosis called the Iowa Fluoride Study (IFS).[82-84] The IBDS collects information about children's demographic, anthropometric, genetic and lifestyle factors, including diet and physical activity, and describes their associations with bone mineral mass and structure.[85] The cohort of 470 4-to-6-year-old children and their parents volunteering for the IBDS were a subset of the 890 families previously recruited, immediately postpartum, from 8 Iowa hospitals between 1992 and 1995 into the IFS, and active in the IFS when the IBDS was established in 1998.[26] The IBDS cohort was 53% female and 96% white, which was similar to the primary study (IFS) and to the population of the State of Iowa.[86] By enrolling into the IBDS, parents and children agreed that the child will participate in periodic physical activity monitoring (to date, at ages 5, 8, 11, and 13 years). This thesis project examines data from those participants whose physical activity data were recorded at the age 5 study timepoint (range 4-7 years of age) and who lived in Iowa at the time of physical activity measurement.

Family Demographics

Socio-demographic data, including parents' educational levels and household income, were obtained at the time of the child's birth (1992-1995), upon enrollment into the IFS. The child's gender and date of birth were recorded upon enrollment as well. Parents' educational levels were again ascertained at the time of IFS participants' dental exams and bone scans at age 5. Income and educational level data were collected in ordinal categorical fashion, as shown in Table 1. When both parents' educational levels were provided, this thesis uses the highest reported level.

Table 1. Parental education and household income categories

Parental Education Level		Annual Household Income	
1	8^{th} grade or less	1	Less than $10,000
2	Some high school	2	$10,000-$19,999
3	High school diploma or GED	3	$20,000-$29,999
4	Some college	4	$30,000-$39,999
5	2 year college degree	5	$40,000-$49,999
6	4 year college degree	6	$50,000-$59,999
7	Graduate or professional degree	7	$60,000 or more
8	Other		

Consistent with a previous study by IFS investigators, this thesis uses three levels of socio-economic status (SES), defined for families based upon parents' educational level and household income:

a. low – less than $30,000 household income per year and neither parent having a 4-year college degree.

b. high – $30,000 or more annual household income and parent(s) with a graduate/professional degree, or household income of $50,000 or more regardless of parents' educational levels.

c. middle – families not meeting criteria for either high or low SES.

According to IFS authors, "the combination of income and educational level was deemed necessary because of the study's central base in Iowa City, a university town with many student families that may temporarily have low income but should not be considered as having low SES."[87]

Anthropometric Measures

The height and weight of each child were recorded at the time of entry into the IBDS, between 4 and 6 years of age.[88] Each child's height and weight were measured at the Clinical Research Unit (CRU) of the Institute for Clinical and Translational Science (ICTS) at the University of Iowa, by trained personnel using a stadiometer and standard physician's scale, respectively. The measuring instruments had been regularly checked for accuracy and precision. Children wore their indoor clothing, but removed their shoes for the height and weight measurements. Heights were recorded in millimeters and weights in tenths of kilograms. These measurements were used to calculate the child's BMI (kg/m^2).[88]

Physical Activity Measures

Accelerometry-Based Physical Activity Monitoring

In the Iowa Bone Development study, children's physical activity was assessed using the ActiGraph physical activity monitor (Pensacola, FL).[88] Raw data (movement counts per minute) were downloaded using an interface and computer. The ActiGraph is a widely used accelerometry-based physical activity monitor. The ActiGraph PAM, as used in the IBDS, collected movement count data that reflected the acceleration at the hip. These data were time-stamped and stored each minute to produce a pattern of activity intensity, frequency, and time.

Parents and children were instructed in person on how to wear the ActiGraph PAM, attached to a belt at the child's waist and positioned at the midaxillary line.[88] Children were requested to wear the ActiGraph PAM for four consecutive days, including one weekend day, during September, October, or November. Parents were instructed to complete a form indicating the times that the activity monitor was attached and detached. PAMs and data sheets were sent to participants and returned via U.S. mail.

Activity data eligible for analysis in this thesis required at least three days of data per child, with at least eight hours of movement counts per day.

Physical Activity Variables

Summary variables were constructed from the activity monitor data: daily minutes of MVPA, and daily minutes of VPA.[88] Using current guidelines from the National Health and Nutrition Examination Survey, thresholds for moderate and vigorous physical activity intensity levels, respectively, were defined as the movement counts per minute which correspond to 4 METs and 7 METs. Using Freedson's prediction equation for age-specific count ranges corresponding to MET levels, the thresholds were 1,281 movement counts per minute (moderate) and 3,581 movement counts per minute (vigorous).[14, 79, 89]

Media Activity Variable

Children of the ages studied here do not have the cognitive ability to report on their own activity.[90] Parents can act as proxy reporters, and have been shown to reliably and validly report the amount of time their children view television (TV).[91] At the time of the IBDS exam in the CRU, parents were asked to report the number of hours per day that the child typically spent watching TV, as well as the number of hours per day that the child typically spent playing videogames. For this thesis, a composite variable representing hours spent in media activity was defined as the total combined TV-viewing and videogame-playing as reported by parents (hours per day). Also, for some analyses, media time was dichotomized as "high" (more than 2 hours per day) or "recommended" (2 hours or less of media time per day), based on American Academy of Pediatrics recommendations.[39]

Residential Data

Federal health care policy typically utilizes one of two major ways to define rural: the Office of Management and Budget's (OMB) "metropolitan-nonmetropolitan" classification of counties, and the Census Bureau's "urban-rural" classification of areas and population.[92] Although some federal programs have developed their own variants of the OMB or Census Bureau classifications, these are the two methods most often used in policy analysis and research.

From the time of enrollment into the IFS, participants' addresses and changes of address (if any) were recorded in study files. The date of each child's physical activity monitoring period was compared to the participating family's study file to obtain the address of residence at the time of physical activity monitoring. For this thesis, each participant's address was characterized as urban or rural, based upon the U.S. Census Bureau's designation of the census block containing the address, as described below (Urban and Rural Characterization). The characterization as metropolitan (metro) or non-metropolitan (nonmetro), according to the county of the children's addresses of residence, will not be used in this thesis. Census block is thought to be a better representation of very young children's immediate environment, whereas the county of residence encompasses many square miles and contains both urban and rural addresses at the census block level.

Urban and Rural Characterization

A census block is the smallest geographic unit of Census statistics.[93] A census block is a subdivision of a census tract, which at the time of its designation contains population and housing types of relatively homogeneous character and is considered useful in defining neighborhood areas and studying their socioeconomic characteristics.[93] Census blocks frequently correspond to individual city blocks bounded by streets; however, in rural areas, census blocks can include many square miles and can include boundaries that are not streets.[93]

Geographic entities such as cities and counties often contain both urban and rural territory at the census block level. As defined by the Census Bureau, urbanized areas

(UA) and urban clusters (UC) consist of a geographic core of census blocks or block groups that have a population density of at least 1,000 persons per square mile, and adjacent blocks or block groups with at least 500 persons per square mile, with a total census population of at least 50,000 (UA) or between 2,500-49,999 (UC). Territory, population and housing units located within an urbanized area or urban cluster are classified as "urban" under the Census 2000; all territory, population, and housing units outside of UAs and UCs are classified as "rural."[93]

The U.S. Census Bureau provides an online tool (www.factfinder.census.gov) that allows a user to identify the county, census tract, and census block for addresses in the U.S. In addition, the UA, UC or rural population figures can be accessed by census block number. For this thesis, these online tools allowed the identification of the census block containing a study participant's address and characterization of the census block as urban (located within a UA or UC census block) or rural (within a rural census block).

Study Variables

Study Population

The study population for this thesis was comprised of participants in the Iowa Bone Development Study who resided in Iowa at the time of the first physical activity monitoring period of the study (age 5) and who provided a minimum of 3-days' physical activity data.

Outcome Variables

The primary outcomes were: 1) daily minutes of MVPA, 2) daily minutes of VPA, and 3) reported hours spent per day on TV and videogames (media).

Exposure Variables

The primary exposure variable was the urban or rural nature of each address, based on the U.S. Census Bureau's classification of the census block containing the participant's address at the time of physical activity monitoring. The dichotomous exposure variable at the census block level identifies the urban/rural nature of the immediate residential locale as compared to the metropolitan/nonmetropolitan county classification used in some other studies. Covariables in this thesis included SES (low, middle, high), child's age (months), and BMI (kg/m^2).

Statistical Methods

The statistical methods used to examine specific aims are outlined below and organized by aim. All aims were tested using SAS 9.1.3 (SAS Institute, Cary, NC). Statistical significance was set at $p<0.05$. Separate analyses were conducted for boys and girls, as children's physical activity has been shown to vary by age and gender.[25, 94]

Specific Aim One

The distributions of the major variables of interest were presented, including mean age and BMI, and the proportion and number of participants in each category of gender, census block type, SES level, and ethnicity/race. The distribution of SES was presented by urban/rural census block for each gender.

Specific Aim Two

The mean levels of MVPA minutes, VPA minutes and media hours were described for each SES level, by gender. Gender-specific analyses were conducted to examine the distributional properties of the variables. Means and standard deviations were calculated. ANOVA analyses, including Tukey's Studentized range tests, were used to determine whether mean activity levels were significantly different among children at different levels of SES. Proportions of children who engaged in higher versus lower levels of MVPA, VPA, and media hours were categorized by three levels of SES.

Specific Aim Three

The mean levels of MVPA, VPA and media hours were described by census block type, by gender, with Student's t-test employed to compare the mean activity times of urban children to those of rural children.

Specific Aim Four

Separate logistic regression analyses were performed for each activity outcome variable (MVPA, VPA, and media), using categorical activity levels as the outcome variable. Logistic regression was chosen in order to investigate children's risk for lower levels of physical activity, rather than using a continuous outcome which would have suggested an incremental difference in daily activity associated with exposure variables. Participants were categorized into levels (low, medium, and high) of MVPA and VPA, with low and high levels, respectively, defined by the gender-specific 1st and 3rd quartiles for mean number of minutes spent per day in MVPA and VPA; the medium categories of MVPA and VPA consisted of those participants below the 3rd quartile and above the 1st quartile of mean minutes per day of MVPA and VPA. This categorization scheme was chosen over using a dichotomous outcome (low versus not-low, or low versus high levels) to allow for inclusion of all subjects' data in analyses to examine for possible different activity levels among groups. Categorization was based on the gender-specific percentiles of our study sample rather than on meeting or exceeding physical activity recommendations because of the shortcomings, described earlier, of current physical activity recommendations for children.[11, 12, 14] In addition, it is not clear how the newer science of accelerometry-based physical activity monitoring of children's activity compares to the self-report measurement methods on which some recommendations are based.

Logistic regression models for each outcome variable used the rural characterization of the residential address as the exposure variable (reference category =

urban). For each outcome variable, an initial model forced in covariates consisting of SES, with scores assigned by level (0=high, 0.5=middle, 1=low); age (in 3-month increments, to account for potential changes in physical activity behaviors with increasing maturity in this young age group); and BMI (weight in kilograms / height in meters^2). The second step for each model was to enter the primary exposure variable (census block) to the model containing the covariables, with examination of whether the addition made a difference as to which covariables' coefficients met the threshold level of significance ($p<0.05$).

The first model used ordinal logistic regression with levels of MVPA as the outcome variable. To examine the association of the urban versus rural residential environment (census block) with children's physical activity levels, the primary exposure variable was the census block classification of the participant's address as urban or rural. Children that resided in urban (UA or UC) census blocks were considered a reference category to investigate the potential effect of residing in rural census blocks on levels of physical activity, by gender, and controlling for age, BMI, and SES.

Other models also used census block type as the exposure variable. Ordinal logistic regression was again used with the outcome variable of VPA (high, medium, low). Logistic regression was used with a dichotomous outcome for media hours (high versus recommended levels).

To ensure the absence of multicollinearity, all full models were run in ordinary least squares (OLS) regression at the recommendation of the Paul Allison text *Logistic Regression Using the SAS System*; when none of the individual variables is significant but the entire set is significant, multicollinearity is likely.[95] Exploratory models including media hours as a predictor variable in the physical activity models (MVPA and VPA) were explored to ensure confidence intervals for media hours odds ratios included the value 1.0. Adding media hours changed neither the significance of other predictors' odds ratio estimates nor the global null hypothesis in any model, justifying the exclusion of media hours from the set of MVPA and VPA predictor variables. Interaction terms (UrbanRural/BMI, BMI/SES, and UrbanRural/SES) were non-significant and thus were omitted from all final models.

CHAPTER IV

RESULTS

Of the 470 families volunteering for the IBDS, valid address and activity data were available for 400 participants residing in Iowa at the time of physical activity monitoring. The demographic variables of interest are presented in Table 2. The mean age of study participants was 5.65 years (standard deviation = 0.53). Females comprised 53.5% of the sample. Mean age and gender ratio were similar to those of the parent study from which data were derived, suggesting that the exclusion of non-Iowa residents and those with incomplete address information was not disproportionate by age or sex in this thesis.[96] More participants lived in an urban (57.8%) than rural environment, and more participant families fit the criteria for high SES (39.3%) than middle (36.5%) or low (24.2%) SES.

Table 3 presents the distribution of SES by block type, for all participants, and for boys and girls separately. Among families living in an urban environment, the largest proportion (44.6%) fit the criteria for high SES, whereas more rural families were in the middle SES category (37.9%) than in the high (31.2%) or low (30.2%) categories.

Distributions of the outcome variables mean daily MVPA, mean daily VPA, and media hours were described by mean, standard deviation, median and percentiles (Table 4).

Mean daily minutes of MVPA and VPA and mean daily hours of media use are displayed by SES level for boys and girls in Table 5. Middle-level SES girls and boys spent about 5 minutes more in daily MVPA than low SES children, and high SES children's MVPA exceeded that of middle-level SES children by a similar amount; differences were not statistically significant. Using Tukey's Studentized range tests, all differences among SES levels for both boys' and girls' mean daily MVPA minutes and VPA minutes were not significantly different from zero at the 95% confidence level.

Table 2. Participants' demographic characteristics

(n = 400)	**Percent**	**n**
Sex		
Male	46.5	186
Female	53.5	214
Census Block Type		
Rural	42.2	231
Urban	57.8	169
SES (Household education and income composite)		
Low	24.2	97
Medium	36.5	146
High	39.3	157
Race/Ethnicity		
White	93.2	372
African American	1.0	4
Hispanic	1.5	6
Asian	<1.0	1
Unreported	3.5	14
Missing	<1.0	3
Age[1]: Mean *(SD)*	5.6 *(0.53)*	
[range]	*[4.5 – 7.7]*	
BMI[2]: Mean *(SD)*	16.1 *(1.79)*	
[range]	*[12.4 - 26.1]*	

[1] Years

[2] weight in kg / height in meters^2

Table 3. Percentage (number) of urban and rural residents at SES levels

	Urban			Rural		
SES	**All**	**Girls**	**Boys**	**All**	**Girls**	**Boys**
High	44.6% (103)	45.2% (57)	43.8% (46)	31.2% (54)	34.1% (30)	29.6% (24)
Medium	35.5% (82)	32.5% (41)	39.0% (41)	37.9% (64)	40.9% (36)	34.6% (28)
Low	19.9% (46)	22.2% (28)	17.1% (18)	30.2% (51)	25.0% (22)	35.8% (29)

Table 4. Data distributions of outcome variables

	Daily Media (hours)		**Mean Daily MVPA (minutes)**		**Mean Daily VPA (minutes)**	
	Girls	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**
n	211	185	214	186	214	186
Mean	2.44	2.49	125.58	145.98	13.77	19.38
Std. Dev.	1.54	1.28	34.18	38.40	9.22	12.22
Minimum	0.25	0.25	39.75	30.50	1.00	1.50
5%	0.75	1.00	74.00	89.75	3.25	4.00
10%	1.00	1.00	83.00	99.50	4.25	5.25
1st Quartile	1.50	1.50	102.00	118.50	7.00	11.25
Median	2.00	2.00	124.25	144.62	12.00	16.75
3rd Quartile	3.00	3.25	145.75	172.00	18.75	24.50
90%	4.25	4.00	167.75	201.50	26.40	35.50
95%	5.50	5.00	187.25	212.00	30.50	43.75
Maximum	9.00	7.00	234.50	260.75	66.50	70.50

Table 5. Mean (SD) daily activity by SES

SES	Girls MVPA[1] (minutes)	Girls VPA[1] (minutes)	Girls Media[2] (hours)	Boys MVPA[3] (minutes)	Boys VPA[3] (minutes)	Boys Media[4] (hours)
High	130.7 (30.9)	14.0 (7.8)	2.0 (1.3)[£,§]	150.6 (37.7)	20.1 (12.7)	2.2 (1.2)[†]
Medium	124.3 (38.7)	14.4 (11.6)	2.6 (1.7)[£]	146.0 (35.9)	18.6 (10.7)	2.5 (1.2)
Low	118.6 (31.1)	12.3 (7.1)	2.9 (1.6)[§]	139.1 (42.6)	19.5 (13.7)	2.9 (1.4)[†]

[1] n = 50 (low SES); n=77 (middle SES); n=87 (high SES)

[2] n = 49 (low SES); n=75 (middle SES); n=87 (high SES)

[3] n = 47 (low SES); n=69 (middle SES); n= 70 (high SES)

[4] n = 46 (low SES); n=69 (middle SES); n= 70 (high SES)

[£]p = 0.0009 (Tukey’s): middle-high SES (0.65 hours; 95% CI: 0.10 – 1.21)

[§]p = 0.0009 (Tukey’s): low-high SES (0.95 hours; 95% CI: 0.31 – 1.58)

[†]p = 0.02 (Tukey’s): low-high SES (0.68 hours; 95% CI: 0.11 – 1.24)

As also presented in Table 5, high SES girls engaged in 0.95 fewer daily media hours than low SES girls (95% CI: 0.31 – 1.58), and 0.65 fewer hours than middle-level SES girls (95% CI: 0.10 – 1.21), also by Tukey’s Studentized range tests. Low SES girls’ mean media use was higher than that of middle-level SES girls (95% CI: -0.36 – 0.94). There was a notable difference of 0.68 hours (95% CI: 0.11 – 1.24) between high and low SES boys’ mean hours per day of media. Other comparisons of media use among boys’ SES groupings (high and middle, middle and low) at the 95% confidence level were not different from zero.

Because the categories of high and low MVPA and VPA were defined based on 3rd and 1st quartiles, respectively, the distribution of participants’ physical activity levels at each SES were similar: not surprisingly, approximately 25% of participants in each SES grouping were in the high and low activity categories, and approximately 50% were in the medium category of activity (data not shown).

The number and percentage of children at each SES level that met AAP media recommendations are shown in Table 6. A larger proportion of both boys (62.9%) and girls (70.1%) in the high SES category met the recommendations for daily media hours than did boys (32.6 %) and girls (38.8%) in the low SES category.

Table 6. Percentage (number) of children at recommended or high media, by SES

Media Use	**High SES**	**Medium SES**	**Low SES**
	Girls (n=211)		
Recommended	70.1 (61)	50.7 (37)	38.8 (19)
High	29.9 (26)	49.3 (38)	61.2 (30)
	Boys (n=185)		
Recommended	62.9 (44)	49.3 (34)	32.6 (15)
High	37.1 (26)	50.7 (35)	67.4 (31)

The mean daily minutes spent by urban and rural girls and boys in MVPA and VPA are shown in Table 7. These are the mean daily number of minutes in which the accelerometry-based physical activity monitor recorded counts at or greater than the threshold for 4 METs and 7 METs, respectively. The differences between urban and rural girls' mean daily MVPA and VPA were quite small (1.45 minutes and 0.45 minutes, respectively). Urban and rural boys had similar mean daily VPA minutes, and rural boys' mean daily MVPA was 5.2 minutes more than that of urban boys (95% CI: -6.00 –

16.40). Urban boys' media use was 0.43 hours per day lower than that of rural boys (95% CI: 0.06 – 0.80) while urban and rural girls' media use was similar.

Table 7. Mean (SD) daily activity by block type

	Girls			Boys		
Block Type	**MVPA**[1] (minutes)	**VPA**[1] (minutes)	**Media**[2] (hours)	**MVPA**[3] (minutes)	**VPA**[3] (minutes)	**Media**[4] (hours)
Urban	125.0 (35.1)	13.6 (9.0)	2.4 (1.5)	143.7 (38.5)	19.1 (12.1)	2.3 (1.2)
Rural	126.4 (33.0)	14.0 (9.6)	2.5 (1.5)	148.9 (38.3)	19.7 (12.4)	2.7 (1.3)
Difference	1.45	0.45	0.17	5.21	0.54	0.43[£]
(95% CI)	(-7.28, 10.83)	(-2.08, 2.98)	(-2.60, 0.60)	(-6.00, 16.40)	(-3.04, 4.11)	(0.06, 0.80)

[1] n = 126 (urban girls); n= 88 (rural girls)

[2] n = 125 (urban girls); n= 86 (rural girls)

[3] n = 105 (urban boys); n= 81 (rural boys)

[4] n = 105 (urban boys); n= 80 (rural boys)

[£] p = 0.02 (Student's t-test)

Table 8 presents the variables used in ordinal logistic regression models, and the resulting odds ratios and 95% confidence intervals for lower levels of MVPA, lower levels of VPA and high media use.

Generally, boys and girls living in a rural census block had decreased odds of lower MVPA and VPA, and increased odds of having high media hours, as compared to those living in an urban census block; however, only the boys' media model showed a significant odds ratio for census block. The global null hypothesis that all coefficients are zero could not be rejected at $p<0.05$ in the physical activity models (MVPA and VPA), but was rejected in the media models for both boys and girls.

Although the predictors in the physical activity models did not explain a significant amount of variability in the data (global null hypothesis not rejected at the 95% significance level), the model for boys' MVPA generated a significant OR for SES, and the model for girls' VPA generated a significant OR for BMI. For boys, low SES was associated with an odds ratio of 2.16 for lower MVPA (95% CI: 1.04 – 4.48). Girls' BMI was associated with increased odds for low VPA; for a 1 unit increase in girls' BMI, the odds of having lower VPA increased by 19% (OR 1.19; 95% CI: 1.02 – 1.39).

The odds for rural girls to exceed recommended daily media hours were not significantly different from that of urban girls, with an odds ratio of 1.03 (95% CI: 0.58 – 1.85). The odds of low SES girls' exceeding daily media recommendations were four times (OR 4.12; 95% CI: 1.95 – 8.71) that of high SES girls.

Boys living in a rural census block had twice the odds for exceeding the recommended level of media hours as compared to boys living in a urban census block (OR 2.11; 95% CI: 1.14 – 3.91). The odds ratio was 2.99 for boys from low (as compared to high) SES families to exceed the recommended level of daily media hours (95% CI: 1.34 – 6.68).

Table 8. Logistic regression model results

	(n = 213)		(n = 184)	
Predictors of Lower MVPA	**Girls**		**Boys**	
	OR	**95% CI**	**OR**	**95% CI**
Rural Census Block	0.89	0.53 – 1.50	0.91	0.51 – 1.60
Age[1]	1.01	0.89 – 1.14	1.05	0.93 – 1.20
Low SES[2]	1.72	0.90 – 3.32	2.16	1.04 – 4.48
BMI[3]	0.95	0.82 – 1.11	1.16	0.99 – 1.35
Predictors of Lower VPA	**Girls**		**Boys**	
	OR	**95% CI**	**OR**	**95% CI**
Rural Census Block	0.90	0.54 – 1.52	0.84	0.48 – 1.48
Age[1]	0.89	0.78 – 1.01	0.91	0.80 – 1.04
Low SES[2]	1.43	0.74 – 2.76	0.99	0.48 – 2.03
BMI[3]	1.19	1.02 – 1.39	1.16	0.99 – 1.36
Predictors of High Media Use	**Girls**[4]		**Boys**	
	OR	**95% CI**	**OR**	**95% CI**
Rural Census Block	1.03	0.58 – 1.85	2.11	1.14 – 3.91
Age[1]	0.88	0.77 – 1.02	1.06	0.92 – 1.22
Low SES[2]	4.12	1.95 – 8.71	2.99	1.34 – 6.68
BMI[3]	1.17	0.99 – 1.39	0.93	0.79 – 1.09

[1] Age: in 3-month increments

[2] Socioeconomic Status: ‘low’ as compared to ‘high’ (reference)

[3] BMI = weight in kg / height in meters^2

[4] n = 211

CHAPTER V

DISCUSSION

A better understanding of the association of young children's residential environment with physical activity is vital to the development of improved interventions to effect change in modifiable behaviors. Such understanding is also essential to improving communities' infrastructures in ways that support healthy behaviors. This thesis investigated whether MVPA and VPA, measured by accelerometry-based physical activity monitoring, were correlated with urban or rural residence of young children in Iowa. Screen-based media use, by parental report, was also examined for urban/rural differences. MVPA, VPA and media use by family SES level were studied as well, using a composite variable of household annual income and highest household education level as a proxy for SES. Rural boys' and girls' daily media hours were greater than those of urban boys and girls. No significant differences were found between urban and rural children's MVPA or VPA, nor between odds ratios for low levels of physical activity. Rural and low SES boys had increased odds for exceeding recommended media use, as did low SES girls.

Demographic Characteristics

The study sample for this thesis was nearly 60% urban, consistent with Census 2000 data in which the Iowa population was 61.1% urban.[81] In this thesis, urban participants were more frequently categorized in the high SES status than were rural participants. Among rural boys, the largest proportion (35.8%) were low SES. According to the 2000 Iowa Child and Family Household Health Survey, four out of ten Iowa children were living in families with household income over $50,000 per year, and 32% were in families with incomes less than $25,000 per year.[97] Income in the state of Iowa does not vary widely between urban and rural areas; in 1999, the poverty rate was 9.1% in both urban and rural Iowa. In U.S. Census 2000 data, median rural household income (all households) and median rural family income (households in which two or more related persons resided) differed by less than 5%; median rural family income was lower, and median rural household income was higher, compared with the urban categories.[81] In the 2000 census, educational status differed between urban and rural Iowans over 25 years of age: 26.4% of urban Iowans, compared to 15.6% of rural Iowans, had completed college.[98]

Activity by Socio-economic Status

Mean daily MVPA and VPA were similar among children from high, middle, and low SES levels. Similar to the findings of this thesis, Voss et al. found no relationship between parental income and mean activity level in a 2007 publication describing accelerometry-based physical activity monitoring of 214 healthy 7- and 8-year-old children in the South-west of England as part of the EarlyBird non-intervention prospective cohort study.[99] Although it has been reported that low SES communities have fewer facilities and structured opportunities to encourage physical activity,[100] Voss found that children from poorer families had the same level of overall activity as those from wealthier families, even though they participated in fewer structured activities.[99] Children apparently compensated for a lack of facilities and structured physical activity by engaging in more unstructured PA. Therefore, recommendations to increase structured play and sport opportunities for low income-children[101] may not necessarily improve physical activity levels.[99]

Although mean daily minutes of MVPA and VPA did not differ significantly among the three SES categories of children in this thesis, hours of media use did. This is consistent with Feldman's 2003 finding that physical activity was unrelated to television-watching or playing videogames in a cross-sectional study of 743 Montreal high-school students assessed via questionnaire.[102]

In this thesis, roughly two-thirds of boys and girls from low SES families exceeded the recommended level of daily media hours, whereas one-third met the recommended level. These approximate proportions were reversed in the high SES category, where only one-third of boys and girls exceeded the recommendation. About one half of middle-level SES children engaged in high levels of media use, and one half met the recommendation. In cross-sectional studies, lower SES has predicted more TV viewing in pre-pubertal German children (n=60) and in U.S. adolescents aged 10-16 years (n=2,389).[103, 104] This is a matter of concern, because children who exceed screen time recommendations are more likely to be overweight; screen time as assessed by survey was positively associated with overweight (using measured body mass and standing height) in a cross-sectional study of 709 elementary school students (ages 7-12) in Minnesota and Iowa.[105] That stated, statistically significant findings may or may not be clinically significant; in a meta-analysis of 30 studies published between 1990 and 2004 (majority of samples from U.S. and Canada, but also Japan, China, United Kingdom, Australia, Belgium, France, Germany and Mexico), Marshall et al. found the effects of TV viewing and video/computer game use on body fatness and physical activity of children and youth were too small to be of clinical interest.[37]

Activity by Census Block Type

This thesis saw no significant difference between odds for low activity levels by urban or rural children; no significant differences were seen between urban and rural children with respect to mean daily minutes spent in MVPA or VPA, not inconsistent with other studies' finding no or equivocal association between activity and rural or urban environments. A 2008 study of self-reported physical activity in 3,416 Iowa children (grades 4-6) found that rural children were slightly more active than urban children, and, in defining a third category of "small city," found that children residing in small cities were slightly more active than either urban or rural children.[80] The 2003

National Survey of Children's Health found lower odds for physical inactivity (by parental report) among rural children than urban children, aged 10-17, after adjusting for covariates including parental income and education.[106] Using the 7-Day Physical Activity Recall (PAR) questionnaire with 138 fifth-grade children in 3 Kansas school districts, Davis et al. (2008) found that rural children paradoxically reported less physical activity and less sedentary activity than urban children; the PAR may not be inclusive of some activities particular to rural children, such as farm-based or animal-care activities.[107] Adults' physical activity has been positively associated with degree of environmental urbanization in the southern U.S. but not in Midwestern and Northeastern states in an analysis by Martin et al. (2005) of over 178,000 participants in 49 states from the 2000 Behavioral Risk Factor Surveillance System.[108] Inconsistencies in findings of the association between urban environment and physical activity levels may be due to the differences in samples and measures used.

Given that rural and urban young children in this thesis engaged in similar daily MVPA and VPA, the higher media use by rural boys may have come at the expense of some form of activity not measured in this thesis, such as light activity. Both lesser amounts of light activity and altered patterns of vigorous activity (i.e., fewer short bursts) have predicted childhood obesity in other studies.[73, 109] A 2004 overview by Eisenmann et al. of children's and adolescents' physical activity and cardiovascular disease risk factors reported that total daily energy expenditure has diminished because of a decline in spontaneous but not voluntary activity, and that media use (although not television viewing) has increased in the past few decades.[15] There is little empirical support for the notion that children's time spent on TV, videogames, or computer use displaces time spent on moderate or vigorous physical activity; in the 2004 meta-analysis by Marshall et al.; this relationship was indeterminate among children aged 4-12 years, and among 0-6 year-olds, there was no association between media use and moderate or vigorous physical activity.[37] In the Iowa Bone Development Study, from which this thesis's data were selected, Janz et al. saw no association between VPA and TV viewing, although VPA and TV viewing were both associated with adiposity in children 4-6 years of age. Sedentary behaviors may affect adiposity in a way that is independent of physical activity.[88] Feldman (2003) similarly found that media use was not associated with diminished physical activity in a cross-sectional study of 743 high school students in Montreal, Quebec.[102]

Relatively few studies have compared very young children's physical activity levels on the basis of urban or rural environment, and cited studies of older children and adolescents are likely to reflect the influence of school facilities and sports programs not used at preschool ages. Arguably, studies of urban and rural adults' activity levels could be more relevant to young children's activity than studies of older children: physically active adults may have the capacity to instill similar habits in their children. In a qualitative study utilizing focus groups in 3 Maine communities, older children's physical activity was positively influenced by parents who engaged in regular physical activity with them and who supported their children's interest in physical activity opportunities.[110] In cross-sectional analyses of over 30,000 adult respondents to the 1998 National Health Interview Survey (U.S.), Patterson et al. found that rural adults were less physically active than their urban peers, even controlling for income and education.[111] In areas where a lesser degree of urbanization predicts lower activity, increased access to family-friendly physical activity facilities could increase very young children's activity by encouraging families to be physically active together.

Odds for High Media Use

This thesis saw increased odds for low SES children to exceed media recommendations as compared to high SES children. For boys only, living in a rural census block was associated with greater odds for exceeding the recommended level of media. This was consistent with our uncontrolled comparisons' findings of more daily media hours for children at low SES and for rural boys, and a greater proportion of low SES children exceeding media recommendations.

Limitations of the Study

As is the case with any cross-sectional analysis, causal relationships among associated variables in this thesis should not be assumed. In addition, study designs that employ a convenience sample are generally subject to participation bias, in that people who are likely to volunteer for a study may not be typical of the more general population from which they are drawn. The results of this thesis may not have been generalizable to all young children in the U.S. or in Iowa.

The SES variable composed of parents' income and educational status may not have appreciated potential separate influences of income and education on study parameters. Using data (n=17,766) from the 1996 National Longitudinal Study on Adolescent Health, Gordon-Larsen and colleagues found an inverse association between schoolchildren's inactivity and maternal education specifically.[112]

It is possible that parents' reporting of children's media use was biased in a way that may have been associated with urban/rural or SES categories.

Analysis of accelerometry-based physical activity monitor data at the one minute level of resolution may have been insensitive to clinically significant short bursts of VPA. However, recommendations for physical activity in children are typically expressed in terms of MVPA;[73] therefore, using one-minute periods of measurement to classify moderate and vigorous activity together is justifiable. Indeed, intermittent bursts of activity have been found to correlate with fitness just as well as continuous activity.[73, 109] Activity data may have been more reliable had the analyses included only participants with 4 or more days of wear and 10 or more hours of wear per day.[77, 113] However, compliance with longer wear times may be difficult, and adequate reliability may be attained with surprisingly short monitoring periods.[114]

Similarities between urban and rural children's physical activity levels in this thesis do not preclude that more refined analyses, taking into account specific attributes of the urban or rural environment, may have shown differences. Environmental aspects that may be associated with the urban or rural nature of the address as well as relevant to children's activity patterns, but were not part of this study, include green space, recreational programs and facilities, perceived and actual crime rates, proximity of destinations (school, retail, parks), and presence of sidewalks. Such attributes may vary by a location's urban or rural designation, but cannot be expected to be identically represented among all urban or all rural areas. Thus the broad labels employed by this thesis and other studies using the Census Bureau categorizations may not be sufficient to capture true differences among geographic areas in Iowa.

Familial parameters that may be important and also may be associated with rural or urban residence, but were unknown for this thesis, include parental BMI, parental health habits, presence of siblings or other children in the household, type of residence (single-family, apartment), and preschool attendance. The 2000 Iowa Child and Family Household Health Survey found 46% of children under age 10 received childcare from someone other than a parent; those under age five are more likely to be in a day care center than with a babysitter.[97] Children in organized child care centers spend more time watching television and viewing videos than do children in homes.[115] The potential importance of preschool attendance is underscored by large differences in physical activity among nine U.S. preschools as found by Pate et al.; attendance at a specific preschool explained more variability in physical activity than did traditional demographic covariates such as race and sex.[116]

Intervention and Policy Implications

Parents

The finding of higher media use by lower SES children and rural boys in this thesis may be a matter of public health policy interest, given that other studies have linked media use to increased risk of overweight and other negative health outcomes.[57, 117] Educational interventions which encourage parents to limit these sedentary behaviors of their children might best be targeted to lower SES and rural populations. Time spent using media, unlike light activity, is mostly uninterrupted by short bouts of physical activity.[73, 109] Thus, children's media use may have an impact on fitness, not by displacing sustained MVPA, but by substituting for light activity. In surveys and focus groups, some parents have been surprisingly unfamiliar with the suspected connection between media use, poor diet quality, and weight in very young children.[118, 119] Moreover, since most children begin watching television by age 2 years,[38] the most effective interventions may be those aimed at parents of very young children.

Preschools

The child care setting is an important venue for shaping the development of young children's activity and dietary habits.[70, 115, 120] Daycare facilities provide an avenue to teach parents and children about daily physical activity targets and appropriate screen-based media use. Instead of a "stick" approach (setting limits or taking away children's media time), a "carrot" approach (providing positive opportunities for other activities such as games and coloring) should be an important goal for preschool providers. Inexpensive, activity-friendly equipment, such as bean bags, balls, balance beams and hoops, was associated with increases in accelerometry-based monitored physical activity of children aged 3-5 (n=64) in a 2005 intervention at a Salt Lake City preschool.[121] Such strategies may benefit low SES and rural families when activity recommendations and interventions are implemented within preschools that serve these populations.

Public Facilities

Rural places tend to lack neighborhoods with comparable-aged children to engage in spontaneous group activity; thus, it may be important to increase structured physical activity opportunities for these communities in particular.[110] Discussing her research on the relationship between obesity and the environment in a 2007 Johns Hopkins publication, Penny Gordon-Larsen explained that poor communities are at a disadvantage for attaining healthy foods and physical activity, directly in terms of availability of supermarkets (rural poor) or indirectly in terms of concerns about crime (urban poor).[122] Voss et al., however, caution against simplistic assumptions. While it is true that low SES children get less opportunity for structured PA, a finding that has evoked recommendations for government interventions to provide more sports facilities and programs for PA, these children often make up for the lack of structured activity by engaging in more unstructured play.[99]

Limited Support for Obesity Prevention Recommendations

The rationale for physical activity recommendations is sufficiently established by the positive association of physical activity with other favorable health outcomes. Further research is needed to formulate evidence-based recommendations intended to attenuate or reverse the childhood obesity epidemic. Despite the abundance of published evidence for the possible causes and cures of childhood obesity, firm conclusions remain elusive. Wofford, after retrieving over 5000 articles on childhood obesity, selected 41 higher quality articles for inclusion in a systematic review published in 2008. She came to the conclusion that strong support is lacking for particular interventions aimed at addressing childhood obesity.[123]

Recommendations for Future Research

According to a report by the Johns Hopkins Center for a Livable Future, "Despite extensive debate in scientific and lay communities, no single reason has been found to explain why obesity rates have risen so dramatically, nor has an agreement been reached as to how to reverse these trends."[122] Eisenmann urges consideration of contributing factors beyond diet and activity.[15] There may be important associations of SES with children's health behaviors that will be better understood as researchers refine the ability to identify and control for components of SES, including, but not limited to, ethnicity, sex, immigration status, and cultural and regional differences.

More detailed characterizations of neighborhood settings are needed to better understand environmental correlates of physical activity. Partnering with experts in geographic information systems geocoding (GIS) and the Global Positioning System (GPS) to enumerate specific components of the residential environment enhances researchers' ability to identify factors that potentially influence children's health behaviors. Describing communities using a broad term such as "rural" does not imply similarity of important attributes. Using data from the 1996 National Longitudinal Study of Adolescent Health (n=20,745) and categorizing participants' address in one of 6 study-defined neighborhood types, Nelson and Gordon-Larsen reported that simple classical urban-suburban-rural classifications mask important complexities of neighborhoods.[124]

At the current time, the great majority of relevant studies are cross-sectional and unable to infer which correlates are, in fact, determinants of children's physical activity behaviors.[125] In cross-sectional studies, the methodology precludes identifying causal relationships (if any) between physical activity and community form. For example, it is not clear whether lack of recreational facilities results in inactivity or conversely whether widespread sedentary habituation results in little demand for supportive infrastructure. More longitudinal studies involving interventions, control groups and/or changes to the built environment (natural experiments) are needed to investigate causality.[126, 127]

CONCLUSION

Because habits formed at a very young age are likely to continue into adolescence and adulthood, it is problematic that many young children do not meet activity and media-use levels recommended for the development of healthy behaviors. In this thesis, the physical activity levels of very young children in rural and urban Iowa did not differ significantly, although media use was significantly higher for rural boys and for lower SES boys and girls. The increased likelihood for rural boys and lower SES children to exceed media use recommendations is noteworthy because television viewing has been associated with risk of overweight in children[31] and specifically in preschool children.[38] Parents and childcare providers should recognize the importance of limiting screen-based recreation and of supplying the means for light play and opportunities for MVPA and VPA. Interventions for decreasing young children's media time, with particular attention to lower SES and rural areas, should be investigated as primary prevention for childhood overweight.

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