Social Science & Medicine 97 (2013) 267–277

Contents lists available at SciVerse ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Physical growth and cognitive skills in early-life: Evidence from a nationally representative US birth cohort

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ARTICLE INFO

Article history:
Available online 11 December 2012

Keywords:
Child
Cognitive
Growth
Height
Infant
Skill
United States

ABSTRACT

This paper establishes associations between length/height and cognitive skills in infancy, toddlerhood, and school-entry. The data come from the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B), a representative longitudinal sample of US children born in 2001. A positive association between length/height and cognition is found as early as 9 months and continues through school-entry. These associations are robust to controls for birthweight and economic status. Early growth is also shown to be a stronger predictor of reading and math skills in kindergarten than attained height. Girls exhibit stronger evidence of this latter result than boys. These findings have implications for the interpretation of early life as a critical period for the growth–cognition relationship.

Introduction

A number of studies have shown that circumstances in childhood have long-standing effects on adult outcomes. Physical growth, cognitive development, and chronic illness during childhood have all been associated with health and productivity outcomes in adulthood (Case, Fertig, & Paxson, 2005; Case & Paxson, 2010; Hart et al., 2004; Power & Hertzman, 1997). These relationships, however, are complex. Research across disciplinary lines devotes considerable effort to addressing the mechanisms by which childhood circumstance extends its reach into adulthood.

Recent research has focused on skill development as one such potential mechanism. Childhood is a period of cognitive, social, and psychological development and the skills attained through this development influence a wide range of adult outcomes from criminal activity to health and earnings (Doyle, Harmon, Heckman, & Tremblay, 2009; Heckman, Stixrud, & Urzua, 2006). The processes that are involved with skill development become active as early as infancy and continue through adolescence (Thompson, 2001). Many studies have identified correlates of skill development such as physical growth and socioeconomic status (SES) that help to identify the types of interventions that may best promote skills (Blau, 1999; Case & Paxson, 2008; Cinnirella, Piopiunik, & Winter, 2011). However most of these studies evaluate school-age children and there is limited work that examines these sorts of relationships in the early years of life. This is potentially an important gap in the literature as early life is characterized by processes that are unique in the stages of human development – for example rapid physical growth and certain types of brain development – and that may indicate early life as a critical period for skill development. It is this notion that motivates recent calls for directing resources to the very young to reduce negative outcomes in the adult population (e.g. Doyle et al., 2009).

This paper addresses the above-mentioned gap in the literature by establishing associations between physical growth and cognitive assessments in infancy, toddlerhood, and school-entry in a contemporary US birth cohort. There are two empirical aims. The first is to estimate associations between contemporary height and cognitive assessments at 9 months, 24 months, 4 years, and kindergarten entry. The second aim is to estimate the relative strength of association from heights at different ages on cognitive outcomes at a given age. These aims address the potential of early life as a critical period for skill development.

The next section provides some background information on early-life growth and cognitive development. This background motivates the conceptual framework for the empirical analysis that follows.

Background

Human growth is fastest during the first years of life. Growth velocity starts at about 18 cm/year in the post-natal period and declines to about 8 cm/year in the second year of life. By age three,

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http://dx.doi.org/10.1016/j.socscimed.2012.12.006

growth has declined to about 6 cm/year where it remains relatively stable until the pubertal growth spurt. The rapid growth in early life is accompanied by key development processes related to cognition. Problem solving, language, and social interaction are among the broad forms of cognition that undergo rapid development in the first years of life. Though much of brain growth occurs *in utero*, the infant brain goes through a “blooming” and “pruning” process (Thompson, 2001). The blooming process is characterized by neurons creating large numbers of synapses (connections) with other neurons. Extraneous connections are eliminated in the pruning stage to a level associated with efficient information processing. Though pruning continues beyond the early years of life it is only during this period that physical and cognitive growth share a simultaneous speed that is sensitive to shared influences such as nutrition, stress, and illness.

A positive correlation between child height and cognition dates back for some time (e.g. Porter, 1892). One of the broader and more contemporary evaluations of this relationship is by Case and Paxson (2008) who find positive associations between height and various assessments of cognitive skills in children aged 5–11 years using several large datasets from the US and UK. Other studies include Downie, Mulligan, Sratford, Betts, and Voss (1997), Humphreys, Davey, and Park (1985), Lawlor et al. (2005), Richards, Hardy, Kuh, and Wadsworth (2002), and Wilson et al. (1986). Though a breadth of work has evaluated the height–cognition relationship in school-age children, few studies exist on such a relationship during the growth periods of infancy and early-toddlerhood. The Case and Paxson (2008) study noted a positive association between height and vocabulary skills in 3-year old children of the Fragile Families and Child Wellbeing Study, a large sample of mostly single-parent households in the US. Their estimate implies a magnitude of around one-tenth a standard deviation (σ) in the standardized vocabulary score per 1σ in height. In another study, Heinonen et al. (2008) document a positive association between length at birth and cognitive assessments at around 4½ years in a large sample of Finnish children. Scores on general reasoning, visual-motor integration, verbal competence, and language comprehension assessments were at least $.1\sigma$ higher per 1σ in length at birth. That study also noted associations of similar magnitude between visual-motor, verbal, and language skills and growth between 5 months and 4½ years. Other studies have noted growth–cognition associations in infants and young children from less-developed regions in Guatemala (Kuklina, Ramakrishnan, Stein, Barnhart, & Martorell, 2006), Ethiopia (Aubuchon-Endsley et al., 2011), and India (Rose, 1994).

There is no consensus on why child height and cognitive development are positively related. Some researchers posit a causal relationship, for example that shorter children are less psychologically mature and therefore disadvantaged in school. However there is limited evidence for this sort of relationship (Kranzler, Rosenbloom, Proctor, Diamond, & Watson, 2000; Sandberg, 2002). There is also little indication that directly augmenting height–growth (for example through hormone treatment) will result in stronger cognitive development (Van Pareren et al., 2004; Wilson et al., 1986).

Explanations therefore turn to factors that influence both growth and cognitive development. Factors during fetal development include maternal nutrition, stress, and genetic/hormonal variations (Behrman & Rosenzweig, 2004; Black, Devereaux, & Salvanes, 2007; Leger et al., 1997; Walker & Marlow, 2008; Yount, DiGirolamo, & Ramakrishnan, 2011). These factors would translate to a birth endowment that drives both future growth and cognitive development. Other influences come about in infancy and childhood such as nutrition and exposure to disease and stress (Almond, 2006; Connolly & Kvalsvig, 1993; Dowd, Zajacova, & Aiello, 2009). These factors would affect the productivity of a given endowment that affects both growth and cognition. Economic status is another potential common influence. Economic status tends to show positive associations to height (Murasko, 2012; Steckel, 1995; Thomas, 1994) and is also generally associated with many of the factors just mentioned (Finch, 2003; Kramer, Seguin, Lydon, & Goulet, 2000). Further, because adult height and earnings tend to be positively related, the double-advantage of having taller and higher-income parents may influence the intergenerational transmission of a height–cognition relationship in children.

Data and methods

Sample

Samples are drawn from restricted-use microdata of the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) sponsored by the National Center for Education Statistics (NCES) of the US Department of Education. This manuscript was sent to the NCES Data Security Office for disclosure review prior to publication, as was required by the terms of the restricted-use data license. The target population of the ECLS-B was all children born in the US during 2001 except for those born to mothers younger than 15 years of age, those who died before 9 months, and those who were adopted before 9 months. The study was designed to yield a representative sample based on three domains: race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, Chinese, other Asian or Pacific Islander, and American Indian/Alaska Native), birth status (very low birthweight, low birthweight, and normal birthweight), and plurality. Children were followed longitudinally over four waves of data collection: 9 months, 24 months, 4 years (preschool age), and kindergarten entry (between 5 and 7 years). Children were directly assessed at each wave for physical, cognitive, and social development. Information was also collected on children’s family and school/child care environments. For a detailed description of the ECLS-B and its sample design, see Snow et al. (2009).

The initial 9-month wave consisted of approximately 10,700 children with parental interviews (confidentiality agreements on restricted-use ECLS-B data require sample sizes to be rounded to the nearest 50). Parental nonresponse over subsequent waves yielded approximately 9850 (24 months), 8950 (4 years), and 6600 (kindergarten) observations on the original cohort. Missing child assessments further reduced sample sizes to 10,200, 9200, 8750, and 6500. The ECLS-B data provide a series of sampling weights that adjust for parental nonresponse and incomplete cognitive assessments. The kindergarten weights further adjust for whether the child entered kindergarten in 2006 or 2007, or repeated the grade level. These weights are applied to all estimation procedures in this study. A nonresponse bias analysis performed by the NCES supports that the sampling weights correct for any bias on the three representative domains of the sample (race/ethnicity, birthweight, and plurality) and a select group of other demographic variables such as parents’ ages, maternal education, and geographic region (Bethel et al., 2007; Wheeless, Ault, Copello, Black, & Johnson, 2009; Wheeless, Ault, & Park, 2008).

Three samples are derived from the ECLS-B for use in this analysis. The first sample includes children with complete parental response, cognitive assessments, and length/height measurements through the 9-month and 24-month waves. Second and third samples include children with data through the 4-year and kindergarten waves, respectively. Missing information on height yields final sample sizes of 8500 for the 9-month and 24-month