Childhood Health Shocks, Comparative Advantage, and Long-Term Outcomes: Evidence from the Last Danish Polio Epidemic *

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Abstract

This paper examines the long-term effects of childhood disability on individuals' educational and occupational choices, late-career labor market participation, and mortality. We merge medical records on children hospitalized with poliomyelitis during the 1952 Danish epidemic to census and administrative data, and exploit quasi-random variation in paralysis incidence in this population. While childhood disability increases the likelihood of early retirement and disability pension receipt at age 50, paralytic polio survivors are more likely to obtain a university degree and to go on to work in white-collar and computer-demanding jobs than their non-paralytic counterparts. Our results are consistent with individuals making educational and occupational choices that reflect a shift in the comparative advantage of cognitive versus physical skills. We also find that paralytic polio patients from low socioeconomic status backgrounds are more likely to die prematurely than their non-paralytic counterparts, whereas there is no effect on mortality among polio survivors from more advantaged backgrounds.

Key words: childhood health shocks, occupational sorting, comparative advantage, mediation, long-term effects

JEL codes: I10,I14,I24,J24

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1 Introduction

A vast body of research—from countries with different levels of economic development and covering a range of time periods—documents that adverse shocks to early childhood health have lasting negative consequences on adult health, human capital, and labor market outcomes (Barker, 1990; Bleakley, 2010a; Almond and Currie, 2011; Currie and Vogl, 2013; Almond et al., 2018). The estimated long-term impacts correspond not only to biological processes, but also incorporate changes in human behavior in reaction to the shock. While a burgeoning literature focuses on identifying parental compensating or reinforcing investments (Almond and Mazumder, 2013; Adhvaryu and Nyshadham, 2016; Sievertsen and Wüst, 2017; Bharadwaj et al., 2018), children may also respond to early life physical health insults by making different educational and occupational choices themselves, in childhood as well as adulthood. Moreover, as most studies examine shocks that impact early childhood well-being on multiple margins (e.g., both physical health and cognitive development), there is less knowledge about whether individuals' behaviors may correspond to shifts in the relative or comparative advantage *across* various inputs into the human capital production function (Cunha and Heckman, 2007; Cunha et al., 2010; Heckman and Mosso, 2014) and the labor market.[1]

This paper focuses on a substantial shock to childhood physical health but *not* cognitive development: paralytic poliomyelitis (hereafter, paralytic polio). Our empirical setting is the 1952 polio epidemic in Denmark's capital Copenhagen and the surrounding Copenhagen medical district. We merge unique historical medical records on the universe of children hospitalized for polio during the epidemic in this area to the 1970 Census and 1980-2013 administrative population register data. We follow childhood polio survivors as they become adults and into older ages, and study their choices regarding education and occupation. We test whether the adversity of childhood physical disability can be mediated by educational investments and occupational sorting that reflect an increase in affected individuals' comparative advantage in cognitive relative to physical ability.[2]

Our empirical approach compares the long-term outcomes of children who were hospitalized for either paralytic or non-paralytic polio. Paralytic polio patients experience paralysis of varying de-

[1]For instance, there is evidence on lasting negative effects of *in utero* and early childhood exposure to diseases that impact both physical health and brain functioning, such as influenza (Almond, 2006; Lin and Liu, 2012), malaria (Barreca, 2010; Bleakley, 2010b; Cutler et al., 2010; Kelly, 2011; Venkataramani, 2012), and pneumonia (Bhalotra and Venkataramani, 2015).

[2]For more formal models of how investments in human capital may take into account differences in health and brawn, see Yamauchi (2008), Bleakley (2010a), and Pitt et al. (2012)

grees, ranging from muscle weakness in an extremity to paralysis of trunk and intercostal muscles. While nearly all individuals with non-paralytic polio fully recover from the infection, paralytic polio survivors are likely to experience lasting physical disabilities even after the acute stage, including a re-occurrence of symptoms (such as muscle weakness, pain, and fatigue) after a period of stability ("post-polio syndrome," see, e.g. Frick and Bruno, 1986; Lønnberg, 1998; Ivanyi et al., 1999; Rekand et al., 2000; Farbu et al., 2006; Tiffreau et al., 2010; Gonzalez et al., 2010; Groce et al., 2014). Importantly, although most survivors of paralytic polio experience some permanent physical disabilities, they are still capable of continuing in mainstream education and entering the labor force after the infection. In our setting, earlier research has documented that only 25 individuals who survived paralytic polio during the 1952 epidemic ended up needing permanent respirator support, and nearly all of them were infected as adults (Warwicker, 2006). For individuals who were infected as children—on whom we focus in this study—the Danish government had an explicit goal of rehabilitation and re-integration into the regular educational system and the labor market.

Our research design relies on the assumption that, *conditional on polio infection and hospitalization*, the incidence of paralysis is uncorrelated with unobservable determinants of individual outcomes. A small medical literature has documented that there are few known risk factors that are associated with paralysis among polio patients (Abramson and Greenberg, 1955; Weinstein, 1957; Lindahl, 1960; Nielsen, 1999; Bunimovich-Mendrazitsky and Stone, 2005), and, as we explain in Section 4, we control for all of them in our analysis. Additionally, we show that children's socioeconomic background—an important predictor of their educational and occupational choices—is uncorrelated with the incidence of paralysis in our sample. The lack of correlation between paralysis and socioeconomic status among polio patients is consistent with earlier findings based on data from the 1952 epidemic in Lindahl (1960).[3]

Our analysis focuses on 1,649 children who were born in 1938-1952 and hospitalized for polio in the Copenhagen Blegdam hospital, the primary hospital that admitted polio cases from the capital

[3] Another concern, which we discuss in Section 4, is selection of individuals into the hospital. Given high public awareness of the epidemic and universal access to publicly-funded hospitals, which provided treatment free of charge, we do not expect this issue to be very severe. Early research on the 1952 epidemic supports the claim that the vast majority of polio patients with symptoms in the area that we study were referred to the Blegdam hospital and assessed by a small number of specialist physicians (Hertel, 1979; Warwicker, 2006). We also show that our hospital records include almost all registered paralytic and a large share of registered non-paralytic polio infections in the Copenhagen medical district, implying that selection into hospital admission was minimal. Finally, because patients were all screened by the same small group of experts at the hospital, it is unlikely that mis-classification of polio status due to diagnostic uncertainty is introducing bias into our analysis.

and the rest of the Copenhagen medical district. We find that, relative to individuals hospitalized for non-paralytic polio, paralytic polio survivors are more likely to continue formal education beyond compulsory schooling and less likely to be employed as unskilled workers at ages 18 to 32. By age 50, individuals who had childhood paralytic polio are not only more likely to have a university degree, but are also in occupations that have lower task requirements in the physical/brawn domains and higher requirements for computer skills. By selecting out of manual work and into computer-intensive jobs, paralytic polio survivors end up in occupations that experienced substantial employment and wage growth over 1960-2010 (Autor et al., 2003; Deming, 2018). As a consequence, although most studies find that adverse early childhood health shocks lower individuals' earnings in adulthood (see, e.g., Almond and Currie, 2011 and Almond et al., 2018 for overviews), we do not detect any significant differences in wage earnings or total income between paralytic and non-paralytic polio survivors. At the same time, at age 50, paralytic polio survivors are more likely to be on disability pension than their non-paralytic polio counterparts. This finding highlights that the modern Danish disability insurance system plays an important role in supporting the most severely impacted polio survivors. Additionally, it suggests that the burden of the polio disease—which has been largely eradicated in developed countries—is still reflected in today's public welfare system.[4]

While our results are consistent with paralytic polio survivors making educational and occupational choices that reflect a shift in their comparative advantage toward cognitive and away from physical skills, we acknowledge several limitations of this interpretation. Our data do not allow us to disentangle whether these effects are driven by changes in individual choices, parental investments, or public policies. Welfare coverage was gradually implemented after the epidemic, so that paralytic polio survivors and their families could apply for modest financial or in-kind support to alleviate the most pressing economic distress due to the illness. As described in Section 2, childhood polio survivors received guidance to pursue educational and occupational paths that were appropriate for their physical capabilities. At the same time, the main focus of the public support system was to integrate children into mainstream education; i.e., children infected with paralytic polio were not by default placed into special or preferential educational tracks and faced the same admissions criteria for higher education as healthy individuals.

[4] See Philipson (2000) for more discussion of the economics of infectious diseases and their associated welfare losses.

Another issue for interpreting our results is about whether paralysis leads to such extreme loss of physical ability that survivors are unable to choose occupations requiring physical skill. If this were the case, then our findings would reflect an absolute loss of options rather than a shift in comparative advantage. Yet two sets of results suggest that comparative advantage is at least part of the story. First, as we show in Section 3, conditional on employment, paralytic polio survivors have jobs throughout the brawn skill distribution. Put differently, it is not the case that there are zero paralytic polio survivors employed in jobs with high physical skill requirements. Second, opting out of high-brawn occupations does not mechanically imply working in jobs with high computer skills requirements; it is possible to select into "low brawn, low computer skills" occupations (e.g.: telephone salespersons, bookmakers, tailors, and some legal professionals). Moreover, this occupational sorting is present even after we condition on educational attainment. We thus argue that the impact of paralytic polio on educational and occupational choices is not driven exclusively by an extreme restriction of options. And since we focus on polio survivors in the capital region of Denmark, we can rule out that differential access to educational programs is driving our results.

Selective survival among polio patients may further impact the interpretation of our findings. We show that although in-hospital mortality exclusively affected paralytic patients, it is largely uncorrelated with individual characteristics among them. Net of in-hospital mortality, paralytic polio patients are not more likely to die during childhood and young adulthood than non-paralytic patients on average. However, among patients from low socioeconomic status (SES) backgrounds, those with paralytic polio are more likely to die at all observed ages than their non-paralytic counterparts.

To address the concern that selective mortality among low SES polio patients drives our long-run results on education and occupation, we perform a bounding exercise (Lee, 2009). For all individuals who are missing in our outcome data (because they are deceased or have emigrated), we impute their outcomes with the most and least favorable values of each outcome, respectively. Even if we assume that all missing individuals had the worst possible outcomes, we still find that individuals who had paralytic polio during childhood choose longer educational tracks geared toward white collar jobs early in their careers than those who had non-paralytic polio. However, when we examine educational attainment and occupation at age 50, the most conservative bounds yield insignificant estimates. Thus, it appears that initial educational and occupational decisions of paralytic polio survivors put them on a higher education track, but some of the longer-run effects on completed education and occupation may be partially driven by selective survival.[5]

More broadly, our results suggest that paralytic polio survivors compensate for the large negative shock to their physical health by making more use of their non-brawn skills through their educational and occupational choices. Our findings echo the discussions by Yamauchi (2008) and Bleakley (2010a), who point out that if individuals make their schooling decisions based on comparing the marginal costs and benefits, educational attainment can be an uninformative measure of the welfare impact of early life health. While worse childhood health may lower the marginal productivity or the marginal benefit of schooling (which is the interpretation in studies showing adverse effects of early life health shocks on human capital attainment), it may also lower its opportunity cost since a child in poor health may have lower earnings capacity in the labor market. Consistent with this idea, prior studies from developing countries and the historical United States show that early life health can have minimal impacts on schooling despite large effects on adult income (Bleakley, 2007, 2010a,b; Cutler et al., 2010; Venkataramani, 2012; Currie and Vogl, 2013).

Our innovation is to focus on adult outcomes observed in a more modern developed country and to find evidence of an *increase* in educational attainment (rather than a null effect) stemming from a large shock to childhood physical health. While it is possible that this result is in part driven by paralytic polio survivors deriving higher consumption value from education than their non-paralytic counterparts, the fact that we document a shift from brawn-based occupations to those requiring skills in computers suggests that the comparative advantage explanation is also relevant.

Our evidence further builds on a small public health literature on the medium and long-term consequences of polio among survivors. Most of this research uses small samples of (selected) polio survivors, who had paralytic or non-paralytic polio, and compares their outcomes to those of never infected individuals (Lønnberg, 1993; Farbu et al., 2001; Farbu and Gilhus, 2002; Nielsen et al., 2003, 2016).[6] Our study is most closely related to Nielsen et al. (2016), who find that Danish

[5]We do not find any statistically significant differences in effects of paralytic polio on educational or labor market outcomes between survivors from low and high SES families (similar to some past studies on other child health shocks, e.g. Currie and Hyson, 1999; Currie and Stabile, 2003).

[6]Studies on 150 to 170 polio survivors in Norway conclude that "the polio epidemics in the 1950s to a surprisingly little degree influenced social characteristics such as education, employment and professional life," even though the survey participants stated that they "regarded their physical handicap as decisive for their choice of profession" (Farbu et al., 2001, p 503). This finding may be due to three factors: (a) small sample sizes may be underpowered to detect differences in some outcomes, such as education; (b) the studies do not distinguish between occupations by their "brawn" content (e.g., the trade and office category could include manual work in a skilled trade as well as white-

polio survivors who were infected in 1940-1954 have higher educational attainment but similar total income after age 40 when compared to a control group of never infected individuals who are matched on age and gender. We make three contributions relative to this work. First, we reduce concerns about the endogeneity of disease incidence by focusing only on individuals infected and hospitalized during the epidemic, and comparing survivors of paralytic versus non-paralytic polio. Second, we provide new evidence on the impact of paralytic polio at *different stages* of the life cycle, and analyze changes in the skill requirements of polio survivors' jobs (rather than focusing on broad occupational groups, as in prior studies). Third, since the historical medical records allow us to observe family background and to identify polio patients who do not appear in our outcomes data due to death (or, possibly, emigration), we consider heterogeneity in effects by SES, and explicitly account for selective mortality with a bounding approach.

2 The 1952 Polio Epidemic in Copenhagen

Polio pathology. Polio is a viral disease that is transmitted through oral and fecal channels. In the late 19th and early 20th century, large epidemics with many paralyzed patients struck countries such as the U.S. and Denmark. Polio became known as "disease of development": Prior to the large epidemics, polio outbreaks were typically smaller in scale and affected infants (who were protected by maternal antibodies). Improved sanitary conditions, however, resulted in less frequent outbreaks among broader segments of the population, including older children and adults, who had not been exposed as infants. These groups experienced more severe polio symptoms (Bunimovich-Mendrazitsky and Stone, 2005; Groce et al., 2014).

While the vast majority of polio-infected individuals do not experience any symptoms, four to eight percent have mild issues such as malaise, fever, or headache, and one to two percent develop symptoms such as stiffness and pain in the back and neck (symptoms similar to a viral meningitis). Only in about one percent of all polio cases in the population the illness develops into paralytic polio, with paralysis of various degrees especially during the acute phase. Although non-paralytic polio patients recover completely, paralytic polio can result in lasting physical disabilities and, in

collar occupations); (c) the studies rely on survey reports among polio survivors, and thus sample selection based on health and socioeconomic status may bias the conclusions. Indeed, consistent with the last point, Nielsen et al. (2003) document that Danish (paralytic) polio survivors have a higher long-term mortality risk than the overall population.

most extreme cases, death (Horstmann, 1963; Melnick, 1996; Armstrong and Cohen, 1999; Nielsen, 1999; Bunimovich-Mendrazitsky and Stone, 2005; Groce et al., 2014). There is no treatment for polio. Patients have to be monitored during the acute stage of paralytic polio, which can last from two weeks to up to three months. After this period, most survivors regain some or all muscle function, and their physical capabilities can be improved through rehabilitation (Monberg, 1940; Nielsen, 1999).

Why do some polio-infected patients develop paralysis while others do not? Existing epidemiological and medical research on the determinants of polio severity remains inconclusive. The few factors that have been shown to be associated with the severity of a polio infection include age at infection, gender, family size, and birth order (Weinstein, 1957; Nielsen, 1999; Nielsen et al., 2002).[7] While some small-scale studies have suggested that genetic factors may predict the risk of paralysis (Van Eden et al., 1983), other studies have not confirmed this relationship (Zander et al., 1979).

In our empirical models, we exploit the residual variation in paralysis occurrence *net of observed risk factors*. We discuss this approach in greater detail in Section 4.

The 1952 epidemic. As noted above, prior to the introduction of the polio vaccine in 1955, Denmark experienced several epidemics. The largest epidemics in both the U.S. and Denmark occurred in 1952, with a total of 34,071 and 5,676 recorded polio cases in the two countries, respectively.[8]

This last Danish polio epidemic was centered around Copenhagen, with the majority of polio cases appearing in northern and northwestern Copenhagen suburbs, where many middle and upper-middle class families with children resided (Hertel, 1979).[9] All suspected polio patients in the capital and the rest of the Copenhagen medical district were referred to a single hospital for central screening: Blegdam hospital. Due to high public awareness of the symptoms (Hertel, 1979; Warwicker, 2006) and as shown in Section 4, records from Blegdam hospital cover up to 90 percent of officially recorded paralytic and non-paralytic cases of the epidemic in this area.

In the initial weeks of the epidemic (from July 24, 1952 onward), the mortality rate for patients

[7]One study also suggests that muscular injections and tonsillectomy surgery in the weeks prior to or physical activity after a polio infection may contribute to the development of paralysis (Von Magnus, 1952). However, the same study concludes that these factors explain very little of the variation in polio severity.

[8]For U.S. figures, see: U.S. Department of Health and Service. (1963) accessed via `https://www.historyofvaccines.org/content/us-polio-cases-1952-1962`; Danish figures from Hamtoft (1953).

[9]The epidemics also spread to other parts of the country in 1953, but with much lower intensity. There was also a final minor polio outbreak in Denmark in 1961, after the introduction of the first oral polio vaccine, with a total of 356 cases.

with respiratory paralysis (the most severe form of paralysis) was very high, at about 85 to 90 percent (Lassen, 1953).[10] In late August 1952, one month into the epidemic, the invention of manual ventilation reduced mortality among patients with respiratory paralysis dramatically (Lassen, 1953; Ibsen, 1954; Warwicker, 2006).[11] In total, 116 paralytic polio patients died at Blegdam hospital during 1952 (Astrup et al., 1989).[12]

What happened to the vast majority of paralytic polio patients who did not die in the hospital? The Danish government's goal was to reintegrate the polio survivors into mainstream society, as quickly and to the greatest extent possible. After hospital discharge, patients with remaining paralysis entered specialized centers for physical rehabilitation and therapy that were run by the national polio association ("Landsforeningen mod Børnelammelse"). The duration of stay at these centers depended on the severity of initial paralysis and could last up to several months or years (Hertel, 1979; Gould, 1995).

Following the hospital stay and physical rehabilitation, two sets of regulations became relevant for polio survivors. First, starting in 1953, disabled polio survivors could apply for public financial support from the Danish welfare program, which was means-tested and granted temporary financial support to individuals in need (Hertel, 1979).[13] Policymakers extended the welfare program's coverage quickly in response to the 1952 epidemic because it left around 200 primary earners unable to support their families due to lasting paralysis (Hertel, 1979). Families with paralyzed children could also apply for financial and in-kind support to cover extra expenses resulting from the child's disability.[14] From 1961 onwards, the national disability pension program granted benefits to individuals with permanently reduced working ability. Eligibility for income support from this program (for polio survivors and others) required having a documented and lasting reduction in work ability.

[10] The only treatment was a negative pressure ventilator, colloquially known as the "iron lung." The hospital only had one iron lung and a small number of alternative devices, which was not nearly enough to serve the unprecedented number of around 50 polio admissions per day (about one third of them paralytic and 6-12 of them with respiratory problems, according to Lassen, 1953). Moreover, the "iron lung" was not very effective in saving lives.

[11] The procedure consisted of tracheotomy with manual bag ventilation through a rubber cuff tube, calling on hundreds of medical students to ensure round-the-clock ventilation. Among the paralytic patients who survived, only 40 percent required assistance with breathing after one month, and about 14 percent after 10 months (Pallis, 1953).

[12] These deaths include all patients admitted with polio. In our main analysis sample, we observe 50 deaths of children in the relevant age group.

[13] Support for disabled individuals was still a part of the general means-tested welfare system rather than a separate benefit program at that time ("lov om offentlig forsorg"). This support included both financial support to maintain a standard of living comparable to the individual's standard of living prior to the disabling condition, and support in the form of access to specialized cars and housekeeping help.

[14] The national polio association additionally administered private funds and donations to support polio survivors with additional financial resources.

Second, in 1960, the government introduced the "law on revalidation," which formally regulated all public efforts to integrate disabled individuals into the educational system and the labor market. The government's primary emphasis for childhood polio survivors—whom we study in this paper—was on their physical rehabilitation, educational progress, and eventual integration into the regular labor market. Specialized hospitals offered children continued physical therapy and tested them with respect to their physical capabilities. Schools and physicians encouraged childhood paralytic polio survivors to pursue educational degrees that were appropriate for their physical capabilities. While enrolled in any education (ranging from vocational training to university programs), children could apply for financial support to help them cover expenses resulting from their disabilities. However, polio survivors had to meet the same requirements for access to educational programs as other children and were not given preferential access (Nielsen, 2011).[15] Paralytic polio survivors therefore attended many different educational programs, ranging from programs in special education (to accommodate their physical disabilities) to regular programs, including universities, which they entered on equal terms with their non-exposed counterparts (Nielsen, 2011). As we show below in Section 3, our data on educational and occupational variables among paralytic polio survivors supports the notion that the majority of them were included in mainstream society.

3 Data and Sample Construction

Polio hospital records. We use records from the Blegdam hospital that contain the dates of admission and discharge, type of polio diagnosis, in-hospital mortality, and information on family structure and the occupation of the household head. Our SES measure is an indicator for the household head being an unskilled worker. We limit our sample to individuals admitted and diagnosed with either non-paralytic or paralytic polio in 1952. We further limit our sample to cohorts born in 1938 to 1952, who were 0 to 14 years old during the epidemic.

We focus on patients who resided in the capital and the surrounding Copenhagen medical district during the epidemic.[16] We omit 107 children with missing information on parental occupation,

[15] As an example, to access the academic high school track, students had to pass an evaluation. This requirement was not waived for children with physical disabilities.

[16] The capital includes the municipalities Copenhagen and Frederiksberg. Suspected cases from the entire island of Zealand (where Copenhagen is located) were admitted to Blegdam hospital (Warwicker, 2006). However, using data from the larger geographic area would raise more concerns about selection into hospital admission. Among residents of the capital and Copenhagen medical district, we observe the vast majority of polio cases in our analysis age group,

family size, or parity at the time of hospital admission. The hospital records have been linked to the central Danish Civil Registration System (CPR) and thus contain personal identifiers for those who were alive and residing in Denmark in 1968. We assume that all hospital records without personal identifiers in 1968 represent patients who died (after discharge from hospital, but at some point prior to 1968). This is a conservative measure of survival because individuals could be absent from the register data for other reasons, such as emigration.

1970 Census data. Using the personal identifier, we merge hospital records to the 1970 Census, which allows us to observe outcomes in young adulthood. We observe individuals' educational attainment and occupational status in 1970 (ages 18 to 32). We create indicators for whether individuals have completed more than compulsory schooling by 1970, are enrolled in any educational program in 1970, report disability pension receipt in 1970, or are employed in an unskilled job (rather than being in education or holding a skilled job), as defined in the Census classification. The definition of a skilled job was an educational requirement.

Administrative outcomes data. We also use administrative data on outcomes measured in 1980-2013. We study survivors' completed education, employment, occupation, disability insurance receipt, and annual wage earnings at age 50 (in year 2000 Danish crowns). Finally, we add information on mortality from 1973 onward.

Occupations and skills. To shed light on occupational choices of polio survivors and assess whether they reflect shifts in comparative advantage of cognitive versus physical skills, we use data on individual occupations at around age 50.[17] We first define blue-collar occupations as those with International Standard Classification of Occupations (ISCO) 1-digit codes 6 to 9, which include skilled agricultural and fishery workers, craft and related trades workers, plant and machine operators and assemblers, and other elementary occupations, such as cleaners, agricultural laborers, and construction workers, among others. The remaining occupations are considered to be white-collar, including managers, professionals, technicians, clerical, service and sales workers.

Then, we combine the occupational data with O*NET, which is a database containing skill

as we discuss below.

[17] To use as many observations as possible with the occupation data that starts in 1991, we use occupation measures at age 50 if available, otherwise with the mode of any occupation at ages 48-52.

requirements for each occupation, to identify each occupation's intensity in specific inputs. Using confirmatory factor analysis on the full set of 52 ability requirements listed in the category "worker abilities," we obtain for each occupation a score on the required ability level in four domains: **cognitive ability**, which includes verbal and quantitative abilities, idea generation and reasoning abilities; **brawn**, which captures physical strength, speed, gross-body coordination, and flexibility; **spatial/vision ability**, which captures visual, auditory, and speech perception requirements; and **dexterity**, which distinguishes fine-motor skills such as finger dexterity from the first "brawn" factor. We also generate an indicator for the task requirement in **computer skills** based on the average of "interacting with computers" and "programming" requirements. The factor analysis was performed on the full Danish population of our analysis cohorts at age 50, and the task requirements are expressed in percentiles of this general population. See Appendix B for further details. Results using alternative skill measures from Autor et al. (2003), Acemoglu and Autor (2011), and Deming (2018) are presented in Appendix A.

Descriptive Statistics. Table 1 presents means of variables used in our analysis, for the whole sample in column (1), and separately for non-paralytic and paralytic polio patients in columns (2) and (3), respectively. The table documents two facts. First, there are large and statistically significant differences between paralytic and non-paralytic polio survivors in several of the adult outcomes measured in the 1970 census and at age 50 in the administrative data. For instance, in 1970, 23 percent of non-paralytic survivors are in education, compared with 34 percent of the paralytic ones. By age 50, 11 percent of paralytic polio survivors have completed university, while only 7 percent of non-paralytic survivors have. Non-paralytic polio survivors are more likely to be in the labor force in 1970 and less likely to be receiving disability insurance at age 50 than paralytic survivors.

Second, these statistics demonstrate that it is incorrect to assume that all (or even most) of paralytic polio survivors experienced an absolute loss of physical ability that prevented them from engaging in any manual labor. In 1970, 32 percent of paralytic polio survivors are on the blue collar track in their educational or vocational training. By age 50, 24 percent work in a blue collar occupation. Moreover, not only do the majority of paralytic polio survivors work at age 50, but many are active in occupations that require brawn. Figure 1 shows the distribution of task requirements in brawn by paralytic status in our sample. While paralytic polio survivors have more mass in the low-brawn range, there is "common support" over the entire range of the task requirement distribution. The graphs for the spatial/vision and dexterity categories look very similar. Further, as we illustrate in Appendix Figures A.2 and A.3 (and confirm in regression versions of this graphical analysis), the same pattern persists when we condition on the individuals' educational attainment.

Finally, as also shown in our descriptive statistics, out of the 736 paralytic patients in our sample, 50 died in the hospital. This selective morality may account for some of the observed differences between paralytic and non-paralytic survivors. Thus, in the following, we more formally examine the differences in outcomes using regression methods, and discuss the potential impact of selective mortality.

4 Empirical Methods

To examine the impact of the childhood paralytic polio during the 1952 epidemic, we estimate the following regression model using our hospitalizations data for admitted polio cases:

$$Y_{it} = \beta_0 + \beta_1 ParaPolio_i + X_i'\rho + \gamma_t + \varepsilon_{it} \tag{1}$$

for each individual i born in year t. Y_{it} is an adult outcome, while $ParaPolio_i$ is an indicator for an individual being hospitalized with paralytic polio. We include a vector of individual-level control variables observed in the hospital records, X_i: indicators for being admitted during the height of the epidemic (August-December 1952), being male, a firstborn, coming from a family of more than two children, residing in the capital (inner city of Copenhagen and Frederiksberg), and having the head of household classified as an unskilled worker. To control for known age effects on the probability of developing paralysis, we also include year of birth fixed effects, γ_t. ε_{it} is the unobserved error term.

Identifying assumptions. To identify the causal effect of having paralytic polio, we rely on the assumptions that among patients hospitalized for polio, the incidence of paralysis is uncorrelated with unobservable characteristics that also impact outcomes, and that there is no differential selection into hospitalization across paralysis status.

While we cannot directly test the first identifying assumption, we provide suggestive evidence for its plausibility by examining correlations between paralysis and individuals' observable characteristics in our sample of hospitalized polio patients. The epidemiological and medical research on the determinants of polio severity and research on the 1952 epidemic highlight two facts about polio severity. The first is that age at infection matters (Abramson and Greenberg, 1955). Aggregate data on the Danish epidemic documents a distinct age pattern of polio infections previously identified in other research: as illustrated in Appendix Figure A.1, children aged 1-4 experienced higher infection rates than children under 1 or in the 5-14 age group. The other fact is that the 1952 epidemic was most severe in northern and northwestern suburbs of the capital. It is also possible that among inner-city residents, a greater share of suspected polio cases (i.e., including those that are less severe) were admitted to the hospital for observation, leading to a negative correlation between inner-city residence and polio severity. Therefore, all of our specifications include year of birth indicators as well as an indicator for residence in the inner-city area.

Column 1 in Table 2 shows results from a regression of paralytic polio status on child-level characteristics available in our data.[18] As predicted, residence in the inner city area is negatively correlated with the likelihood of being diagnosed with paralytic polio in our sample. However, importantly, none of the other characteristics—including child gender, family background, family size, birth order, and admission in January-July 1952 (before the height of the epidemic)—is a statistically significant predictor of paralytic polio. The lack of a relationship between family SES and polio severity is consistent with earlier research, which documented that the 1952 epidemic affected a broad spectrum of the population, and did not only hit disadvantaged households (Lindahl, 1960; Hertel, 1979). In other words, "everybody knew somebody with polio" during the epidemic. Reassuringly, conditional on year of birth indicators and inner-city residence, our five available observable characteristics do not jointly predict paralytic vs non-paralytic status (the p-value from this joint test is 0.19).

Column 2 in Table 2 suggests that the same individual-level characteristics also have little relationship with the likelihood of children's in-hospital mortality (the p-value of this conditional joint F-test is 0.49), although we do find that individuals residing in the capital are less likely to die

[18] The share of paralytic cases is about 45 percent, which is consistent with medical estimates that about half of all polio patients *with symptoms* (i.e., those who would end up hospitalized) experience paralysis.

in the hospital than individuals outside the capital (reflecting the described geographic differences in the severity of the epidemic). To address this issue, we have estimated all our main models using only polio patients who are capital residents, finding very similar results (available upon request). In sum, the above evidence is consistent with the residual variation in paralysis within our sample as being close to random, and thus serving as a natural experiment to identify the effect of childhood disability on long-term outcomes.

Finally, to show that it is unlikely that selective hospital admission drives our results, we compare our raw hospital records to aggregate statistics of paralytic and non-paralytic polio cases for the capital and the rest of the Copenhagen medical district (Hamtoft, 1953). As Appendix Table A.1 illustrates, our records contain around 90 percent of all paralytic polio cases that were registered for individuals aged 0 to 14 during the epidemic. Moreover, in the hospital records, we observe all deaths from paralytic polio that were registered. When comparing the hospital records to aggregate statistics for all age groups, we cover at least 84 percent of all registered non-paralytic cases. While the non-paralytic statistic is not available by age, anecdotal evidence suggests higher hospital admission rates for suspected polio infections in children than adults (Warwicker, 2006). Thus our coverage of children with non-paralytic polio is likely higher than 84 percent.

5 Results

Table 3 presents our main results for the effect of paralytic polio on educational and occupational outcomes. Panel A shows that, compared to non-paralytic polio survivors, individuals who had paralytic polio are 6 percentage points (15 percent) more likely to have completed more than compulsory schooling and 4 percentage points (22 percent) less likely to be in unskilled work when they are between 18 and 32 years old. Importantly, during this early career stage, we do not observe a significant effect of paralytic polio on the probability of disability insurance receipt. This finding supports the interpretation that the majority of paralytic polio survivors integrated into the regular educational system and the labor market.

The coefficients on the unskilled family background indicator are opposite-signed for all outcomes, consistent with the idea that individuals from low SES backgrounds end up on lower educational and occupational trajectories regardless of paralysis status. Our results further suggest that childhood paralysis may reduce the high-versus-low SES gap in attaining more than compulsory education and in becoming an unskilled worker by about 24 and 33 percent, respectively.

By age 50, paralytic polio survivors are 3 percentage points (36 percent) more likely to hold a university degree and 5 percentage points (20 percent) less likely to work in a blue-collar occupation than non-paralytic survivors (Panel B). The effect for university education is sizeable, especially relative to the sample mean of 8 percent. We also analyzed the total completed years of schooling (a measure which combines schooling at various educational programs) and found no significant differences between paralytic and non-paralytic polio survivors. Thus, it appears that paralytic polio influenced survivors' decisions to go into educational programs with academic tracks but not the total quantity of schooling (as some vocational programs are similar in duration to academic ones).

Paralytic polio survivors are also 8 percentage points (50 percent) more likely to be on disability insurance at age 50, and 5 percentage points (7 percent) less likely to be employed than their non-paralytic polio counterparts. There is no statistically significant effect on wage earnings. The 95% confidence interval, converted into year 2000 dollars, ranges from -\$4,534 to \$3,323 annually. This corresponds to roughly -12% to +9% of average annual earnings in this sample. Supplementary analysis shows equally inconclusive results for a measure of total annual income that combines benefits and wages.[19] These results highlight the significant role of the disability insurance program for paralytic polio survivors as a source of their income in older ages.[20]

The evidence presented above suggests that paralytic polio survivors are more likely to pursue higher academic-track education (i.e., a university degree) despite an expectation of a shortened work life. This result may seem at odds with the prediction from a standard human capital framework (e.g., Ben-Porath, 1967) in which a shorter time horizon for earning income should decrease the expected returns, leading to lower investments in education. Our finding of an opposite effect suggests that there may be additional factors counteracting the reduction in expected returns. Such factors include: a shift in the comparative advantage of cognitive relative to physical skills, a decrease in the opportunity cost of education (Yamauchi, 2008; Bleakley, 2010a), and an increase in

[19] We prefer to report the result for annual earnings because the data on total income has a data break in 1993. Results for total income are available on request.

[20] In supplementary analysis, we show that our results are similar when we focus on a sub-sample of patients admitted to the hospital after August 1952, following the introduction of manual ventilation (that improved survival chances of the most severely paralysed individuals). These results are available on request.

the consumption value of education.

While we cannot separately identify each of these three channels, our evidence on skill requirements is consistent with comparative advantage. Panel C of Table 3 shows that employed paralytic polio survivors are working in jobs that require less physical body strength, dexterity, and spatial and vision ability at age 50. In terms of percentiles of the entire population of the same age, paralytic polio survivors work in jobs that are 8 percentiles lower in skill requirements for physical strength, speed, coordination, and flexibility than their non-paralytic counterparts. Their occupations tend to not be any higher in the overall cognitive requirement (column 1 of panel C), despite their higher educational attainment. However, we find that paralytic polio survivors hold jobs that are 5.6 percentiles higher in the frequency and intensity of computer use (column 5 of panel C) than non-paralytic polio survivors. Further, as shown in Appendix Figures A.2 and A.3, the shift away from occupations heavy in brawn toward occupations requiring computer skills occurs among paralytic polio survivors in both the high and low education groups.[21]

Did paralytic polio survivors get a "head start" on reaping the benefits of technological change over the second half of the 20th century by switching from brawn-based occupations to those requiring computer skills? While we cannot answer this question directly (as we do not observe initial occupational choices at the start of individuals' careers), we can examine whether the occupational choices we observe at age 50 have task requirements that have been shown to have experienced wage gains or losses by prior research (Autor et al., 2003; Acemoglu and Autor, 2011; Deming, 2018). Specifically, in Appendix Table A.2, we document that paralytic polio survivors are less likely to be in routine manual or non-routine manual jobs, which have experienced declines since 1960 and 1980, respectively (Autor et al., 2003).

Paralytic polio survivors instead select into non-routine analytical jobs (Deming, 2018), which experienced wage gains. Importantly, selection into jobs requiring non-routine analytical tasks is not a mechanical consequence of selection out of brawn jobs—there are many jobs that are low or high in both requirements. Lastly, although paralytic polio survivors are more likely to be in jobs that have experienced wage growth, they do not shift into interactive, social, or service jobs, which witnessed the largest gains.

[21] Recall also that the two domains are not mechanically related, i.e., it does not follow that all "low-brawn" occupations are "high-computer-skills" occupations. It is possible to be employed in a "low-brawn, low-computer-skills" occupation.

Selective mortality and heterogeneity by family background. All the results presented so far use data on individuals who survive until 1970 and age 50, respectively. As mentioned above, mortality in the hospital only affected paralytic patients. Within that group, there is little correlation between individual characteristics and the likelihood of death. Moreover, when we exclude the 50 patients who died in the hospital, the remaining paralytic polio patients are not more likely to die during young adulthood than non-paralytic patients (Appendix Table A.3).

This average masks heterogeneity in mortality effects, however. Table 4 shows that paralytic polio patients from low SES backgrounds face an increased risk of early mortality. This result holds both when including and excluding individuals who died in the hospital. By contrast, we do not find any evidence of heterogeneity in effects of paralytic polio on the educational and occupational outcomes by SES (results available upon request).

To address the issue of selective mortality among low SES polio patients, we implement a bounding exercise following Lee (2009). We include all individuals that leave our data prior to the time of measurement with either the most or least favorable outcome, and perform our main analysis on the resulting sample with imputed variables. As we document increased mortality among children from low-SES families (who are likely to have relatively worse adult outcomes), our estimates that impute the "least favorable" outcomes represent a conservative lower bound for the true effects of paralytic polio.

Table 5 presents the results from this bounding exercise for our census outcomes, while Appendix Tables A.4 and A.5 do so for outcomes at age 50. We find that the result for continuing beyond compulsory schooling is robust to the bounds, suggesting that the impacts for educational investments in childhood and young adulthood are not purely driven by changes in sample composition due to selective mortality of the "weakest" paralytic polio survivors. However, results for outcomes at age 50 are more mixed, with the most conservative bounds often yielding insignificant effects (for example, for university education and our measure of jobs that require computer skills). The most robust finding across the lower and upper bounds for this age group is that of an increased probability of being on disability insurance.

Taken together, our conservative bounding analysis suggests that while paralytic polio survivors enter higher educational tracks in young adulthood, the longer-term effects on completed education and occupation may be in part driven by selective survival.

6 Conclusion

Do individuals alter their educational and occupational choices in response to childhood physical disability? We examine this question in the context of paralytic polio, which is a disease that impacts physical health but not other inputs into human capital production or productivity on the labor market. We link historical hospital records on polio patients to census and administrative population register data from Denmark, and compare the outcomes of children who were hospitalized for paralytic and non-paralytic polio at ages 0 to 14 during the 1952 polio epidemic in the Copenhagen area. Our analysis exploits the quasi-random residual variation in paralysis among polio patients after conditioning on the few known medical risk factors. We study outcomes in young adulthood (in 1970) and around age 50.

Our results show that relative to their non-paralytic counterparts, paralytic polio survivors are more likely to pursue higher (academic) education that leads to a white collar job, to choose a white collar track early in their careers, and to obtain university degrees and work in jobs demanding computer skills and less physical skills by around age 50. At the same time, by age 50, paralytic polio survivors are more likely to be on disability pension than non-paralytic survivors.

This evidence is consistent with the idea that paralytic polio survivors respond to a shift in their comparative advantage of cognitive relative to physical skills by obtaining more academic education and selecting out of brawn jobs and into jobs requiring computer skills. Our results also highlight the success of the Danish society in integrating polio survivors into mainstream education and the regular labor market. While we cannot disentangle the separate roles of individual choices, parental investments, schools, and public programs, it is likely that all of these channels contributed to the effects on education and occupation that we see in our data. Importantly, our results are not purely driven by lack of choices for paralytic polio patients—we observe paralytic and non-paralytic polio survivors in occupations throughout all parts of the brawn distribution.

Finally, we find that although there is no evidence of differential mortality between paralytic and non-paralytic patients overall, the mortality risk for paralytic patients is higher for children from low SES than high SES backgrounds, even in the very long run. This result suggests that children from more advantaged backgrounds may be better able to buffer against the lasting health impacts of childhood disability than their less advantaged counterparts.

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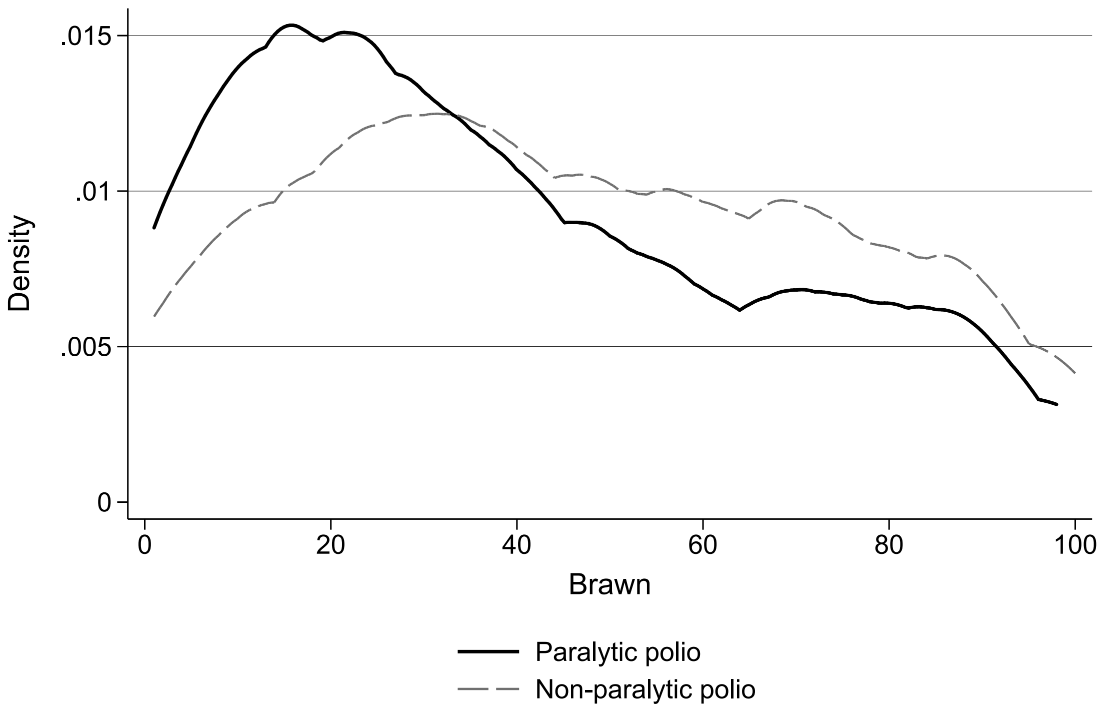
Figures and Tables

Figure 1: Distribution of Task Requirement in Brawn by Polio Status



Notes: This figure shows the distribution of task requirements in brawn by paralytic status for individuals of our sample who have a registered occupation in any of the 5 years around age 50. The scale of the task requirements is in percentiles of the general population. The sample for the kernel density includes children admitted with non-paralytic or paralytic polio and aged 0-14 in 1952, who are observed in the administrative registers at age 50.

Table 1: Summary Statistics by Polio Status During the Epidemic

	(1) All	(2) Non-paralytic	(3) Paralytic
Hospital records			
Year of birth	1946.91	1946.29	1947.67
Age in 1952	5.06	5.65	4.26
Age <=4	0.53	0.45	0.64
Male child	0.58	0.59	0.57
Firstborn	0.48	0.49	0.45
> 2 children in family	0.35	0.37	0.32
Unskilled background	0.34	0.35	0.32
Capital (Copenhagen/Frederiksberg)	0.70	0.75	0.65
Death in hospital	0.03	0.00	0.07
1970 Census data			
In education	0.28	0.23	0.34
In labor force	0.34	0.37	0.30
Brawn Track	0.37	0.40	0.32
While collar track	0.42	0.43	0.41
Assumed death after discharge (before 1970)	0.07	0.07	0.06
Administrative data			
Age at death, no hosp. mort.	53.63	54.62	52.39
Death by 50, no hosp. mort.	0.13	0.13	0.13
Death by 60, no hosp. mort.	0.21	0.20	0.22
University Education	0.09	0.07	0.11
Compulsory education only	0.28	0.29	0.26
Years of education	12.26	12.11	12.45
Disability Insurance	0.16	0.13	0.20
Employed	0.67	0.68	0.65
Annual wage earnings (year 2000 DKK)	237,005	239,019	234,270
Annual total income (year 2000 DKK)	296,154	293,271	300,069
Blue-collar occupation	0.28	0.30	0.24
N	1,649	913	736

Notes: The sample includes children admitted with polio to the Blegdam hospital. We limit to children aged 0-14 in 1952 and residing in the Copenhagen medical district. The variables in administrative data are measured at age 50 unless otherwise specified.

Table 2: Predictors of Paralytic Polio and Death at the Hospital During the 1952 Epidemic

	(1) Paralytic polio	(2) Death in hospital
Male child	-0.016	0.004
	[0.024]	[0.009]
Unskilled background	-0.033	0.011
	[0.025]	[0.009]
Capital	-0.095***	-0.027**
(Copenhagen/Frederiksberg)	[0.026]	[0.011]
Firstborn	-0.029	0.012
	[0.027]	[0.009]
> 2 children in family	-0.037	0.017*
	[0.029]	[0.010]
Hosp. admission Jan-July	-0.119*	0.018
	[0.064]	[0.032]
Mean, dept. var.	0.45	0.03
P-value joint F-test		
(cond. on YOB and capital indicator)	0.19	0.49
Adj. R^2	0.06	0.01
Observations	1,649	1,649

Notes: Robust standard errors in brackets. Both models control for year of birth fixed effects (YOB). The sample includes children aged 0-14 in 1952 who reside in Copenhagen and its medical district, who are admitted to hospital with paralytic or non-paralytic polio. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

Table 3: Effects of Childhood Paralytic Polio on Long-Term Outcomes

	A. Young Adult Outcomes. 1970 Census				
	(1)	(2)	(3)	(4)	
	>Comp. Edu	In Edu	Disab.Ins.	Unskilled work	
Paralytic polio	0.060**	0.036	0.005	-0.037*	
	[0.025]	[0.023]	[0.008]	[0.020]	
Unskilled background	-0.251***	-0.167***	0.019*	0.114***	
	[0.025]	[0.021]	[0.010]	[0.022]	
Mean, dept. var.	0.393	0.275	0.026	0.171	
Observations	1,487	1,493	1,493	1,493	
	B. Education and Labor Market Outcomes, Age 50.				
	(1)	(2)	(3)	(4)	(5)
	Univ.Edu	Employed	Disab.Ins.	Blue-collar Occ	Wage Earnings
Paralytic polio	0.032**	-0.047*	0.079***	-0.055**	-3,863
	[0.016]	[0.027]	[0.021]	[0.026]	[12,193]
Unskilled background	-0.096***	-0.090***	0.103***	0.145***	-72,968***
	[0.012]	[0.028]	[0.022]	[0.028]	[11,014]
Mean, dept. var.	0.088	0.668	0.159	0.278	237,004
Observations	1,427	1,401	1,417	1,242	1,377
	C. Skill Requirements, Age 50.				
	(1)	(2)	(3)	(4)	(5)
	Cognitive	Brawn	Spatial/Vision	Dexterity	Computer Skills
Paralytic polio	0.980	-7.949***	-6.873***	-4.408***	5.609***
	[1.704]	[1.638]	[1.591]	[1.687]	[1.723]
Unskilled background	-11.854***	4.511***	3.882**	6.624***	-5.296***
	[1.736]	[1.714]	[1.650]	[1.722]	[1.780]
Mean, dept. var.	53.006	42.769	44.765	45.261	54.870
Observations	1,265	1,265	1,265	1,265	1,265

Notes: Robust standard errors in brackets. The sample in panel A includes children admitted with non-paralytic or paralytic polio in 1952 who are observed in the 1970 census, at which point they are 18-32 years old. The sample in panel B includes children admitted with non-paralytic or paralytic polio in 1952, who are observed in the administrative registers at age 50. Outcomes in Panel B are measured at age 50 (or five years around age 50 with the indicator for blue-collar occupation). Annual earnings in DKK are deflated to 2000. The sample in panel C includes children admitted with non-paralytic or paralytic polio in 1952 who are observed in the administrative registers at age 50 and who have a registered occupation in any of the 5 years around age 50. We limit to children aged 0-14 in 1952 and residing in the Copenhagen medical district. All regressions control for indicators for a male child, for the child being first-born, for a large family (more than two children), for residence in the capital, for hospital admission January-July, and for birth year. "> Comp. Edu" refers to having education beyond compulsory schooling, and "Disab.Ins." stands for receipt of disability insurance. "Unskilled work" indicates work in an occupation with no educational requirement, as opposed to working in a skilled occupation or being in education . $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

Table 4: Heterogeneity in Effects of Paralytic Polio by SES Background on Likelihood of Missing from Outcome Data and Death by Age; excl. In-Hospital Mortality

	(1) No merge 1970	(2) Death by 45	(3) Death by 50	(4) Death by 60
Paralytic*Unskilled background	0.046*	0.074**	0.093**	0.103**
	[0.027]	[0.035]	[0.038]	[0.046]
Paralytic polio	-0.029*	-0.031	-0.033	-0.002
	[0.016]	[0.020]	[0.022]	[0.026]
Unskilled background	-0.016	-0.014	-0.019	0.012
	[0.017]	[0.022]	[0.024]	[0.029]
Mean, dept. var.	0.066	0.108	0.132	0.209
Observations	1,599	1,599	1,599	1,599

Notes: Robust standard errors in brackets. The sample includes all children admitted with non-paralytic or paralytic polio in 1952, except for the 50 paralytic polio patients for whom we observe an in-hospital death in the data. No merge to the 1970 Census (column 1) is interpreted conservatively as death by 1970. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

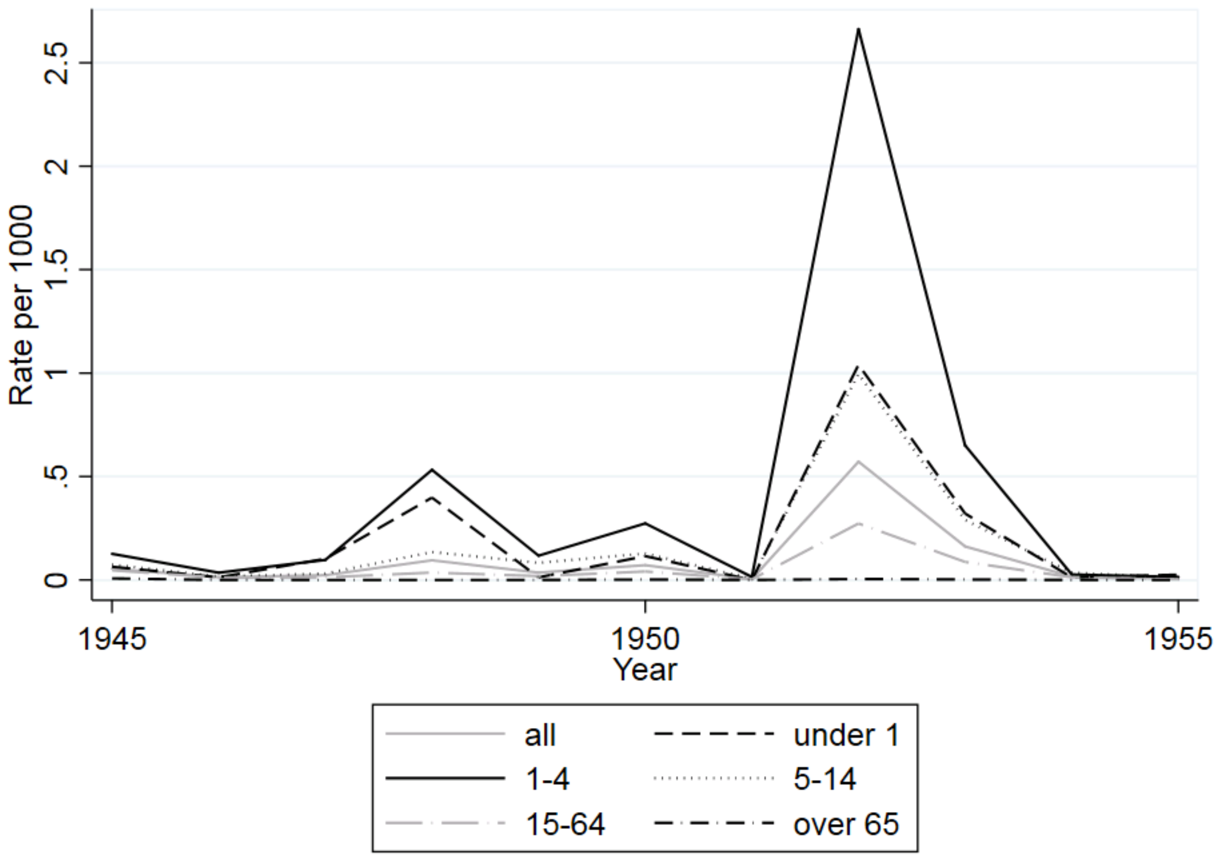
Table 5: Young Adult Outcomes, Bounding Exercise. Census Data, 1970

	A. Baseline Results			
	(1) >Comp. Edu	(2) In Edu	(3) Disab.Ins.	(4) Unskilled work
Paralytic polio	0.060**	0.036	0.005	-0.037*
	[0.025]	[0.023]	[0.008]	[0.020]
	B. Impute Outcomes of Deceased as Least Favorable			
	(1) >Comp. Edu	(2) In Edu	(3) Disab.Ins.	(4) Unskilled work
Paralytic polio	0.044*	0.021	0.053***	0.003
	[0.024]	[0.021]	[0.017]	[0.022]
Mean, dept. var.	0.356	0.249	0.118	0.249
Observations	1,643	1,649	1,649	1,649
	C. Impute Outcomes of Deceased as Most Favorable			
	(1) >Comp. Edu	(2) In Edu	(3) Disab.Ins.	(4) Unskilled work
Paralytic polio	0.094***	0.071***	0.003	-0.046**
	[0.025]	[0.024]	[0.007]	[0.018]
Mean, dept. var.	0.451	0.344	0.024	0.155
Observations	1,643	1,649	1,649	1,649

Notes: Robust standard errors in brackets. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$. For further notes, see Table 3.

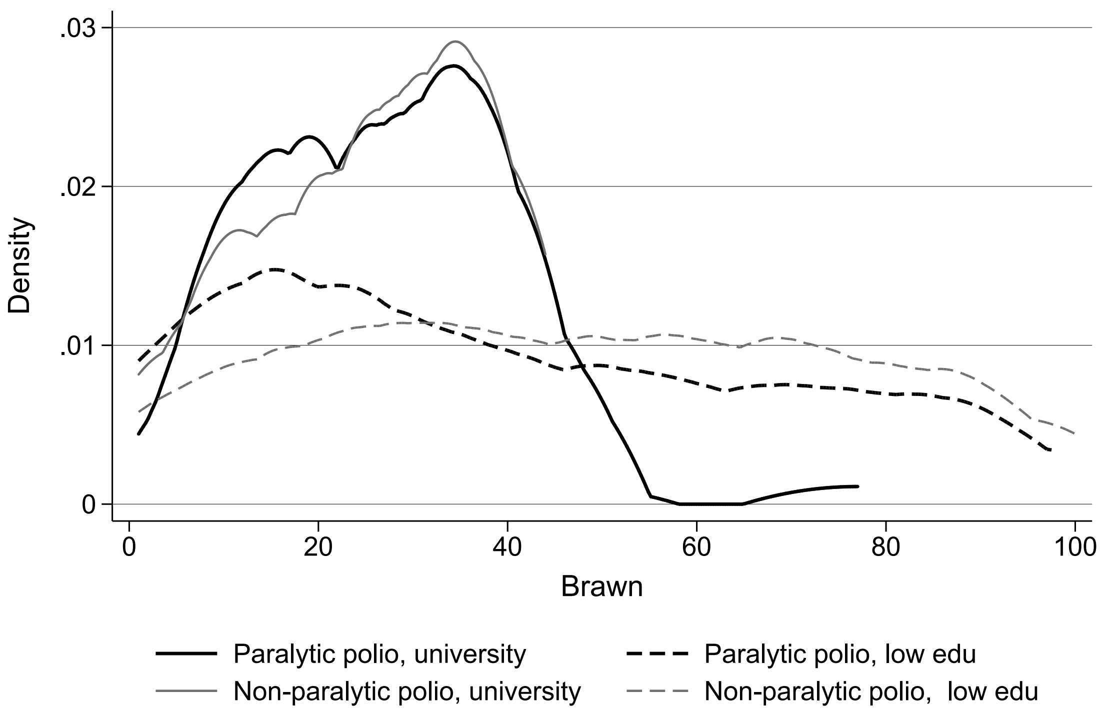
A Additional Results

Figure A.1: Prevalence of Polio by Year and Age Group



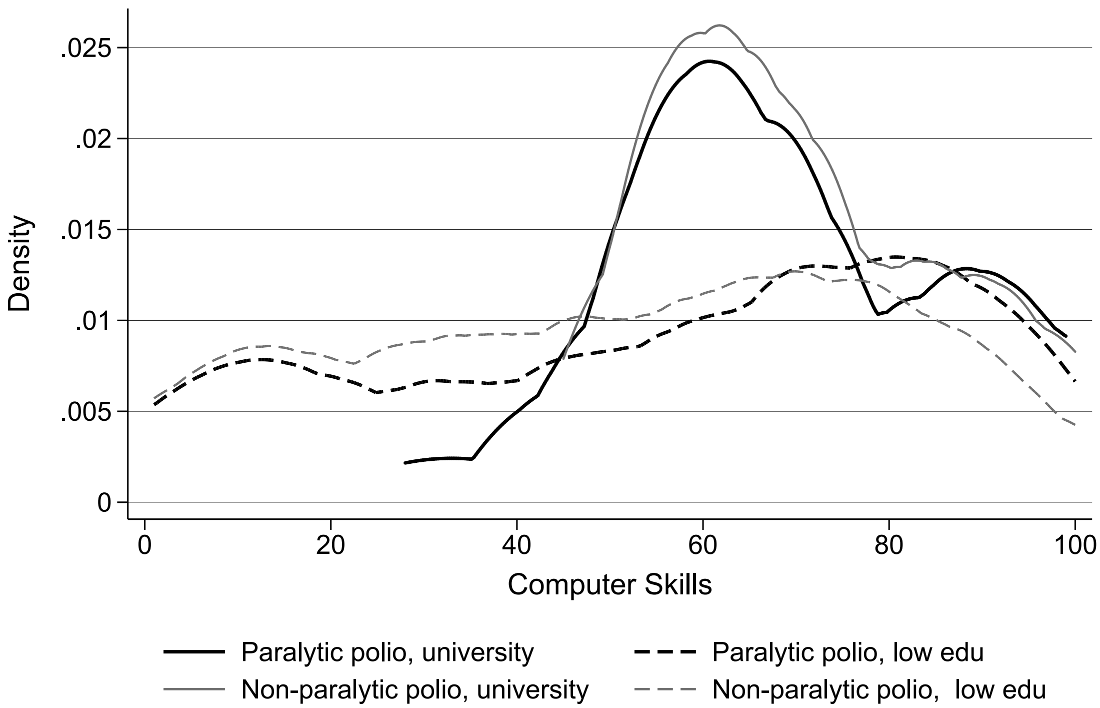
Notes: The data for this graphs comes from aggregate statistics collected and published by the Danish National Board of Health. The y-axis corresponds to the prevalence of (non-paralytic and paralytic) polio per 1000 individuals in the 1950 population, 1945-1955.

Figure A.2: Distribution of Task Requirement in Brawn by Polio and Education



Notes: This figure shows the distribution of task requirements in brawn by paralytic status and education for individuals of our sample who have a registered occupation in any of the 5 years around age 50. The scale of the task requirements is in percentiles of the general population. The sample for the kernel density includes children admitted with non-paralytic or paralytic polio and aged 0-14 in 1952, who are observed in the administrative registers at age 50.

Figure A.3: Distribution of Task Requirement in Computer Skills by Polio and Education



Notes: This figure shows the distribution of task requirements in computer skills by paralytic status and education in our sample.The figure includes children admitted with non-paralytic or paralytic polio and aged 0-14 in 1952, who are observed in the administrative registers at age 50 and who have a registered occupation in any of the 5 years around age 50. The scale of the task requirements is in percentiles of the general population.

Table A.1: Comparison of Raw Hospital Records and Aggregate Statisticcs for Copenhagen Medical District

	Hospital records	Aggregate data	Share covered
Paralytic cases, age 0-14	803	897	0.895
Paralytic deaths, age 0-14	54	50	1.080
Paralytic cases, all ages	1,122	1,280	0.877
Non-paralytic cases, all ages	1,356	1,619	0.838

Notes: Own calculations based on all Blegdam hospital records (including individuals with missing data on covariates, who are omitted from our main analyses) and Hamtoft (1953, 1955) for aggregate data on the capital and the surrounding Copenhagen medical district. We compare case numbers and deaths during the 1952 epidemic in two age groups.

Table A.2: Occupational Status and Skill Requirements. Administrative Data, Age 50

A. Indicators as in Autor, Levy, Murnane (2003)					
	(1) Non-routine cognitive: Analytical	(2) Non-routine cognitive: Interpersonal	(3) Routine cognitive	(4) Routine manual	(5) Non-routine manual physical
Paralytic polio	0.060	-0.049	0.070	-0.107**	-0.171***
	[0.047]	[0.048]	[0.047]	[0.045]	[0.048]
Unskilled background	-0.335***	-0.253***	0.072	0.239***	0.215***
	[0.048]	[0.047]	[0.049]	[0.047]	[0.049]
Mean, dept. var.	-0.143	0.104	0.086	-0.130	-0.202
Observations	1,214	1,214	1,214	1,214	1,214
B. Indicators as in Deming (2017)					
	(1) Nonroutine Analytical	(2) Social perceptiveness	(3) Routine	(4) Service	
Paralytic polio	0.135*	0.118	0.234***	-0.090	
	[0.070]	[0.092]	[0.088]	[0.073]	
Unskilled background	-0.282***	-0.556***	0.141	-0.235***	
	[0.073]	[0.094]	[0.093]	[0.074]	
Mean, dept. var.	3.863	4.475	4.648	5.202	
Observations	1,214	1,214	1,213	1,214	

Notes: Robust standard errors in brackets. Same sample of polio-survivors with a registered occupation in any of the 5 years around age 50 as in Table 3. Panel A replicates the skill measures from Autor et al. (2003), updated for O*NET in Acemoglu and Autor (2011). Panel B replicates the skill measures from Deming (2018). $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$.

Table A.3: Effect of Paralytic Polio on Likelihood of Missing from Outcome Data by Age; excl. In-Hospital Mortality

	(1) No merge 1970	(2) Death by 45	(3) Death by 50	(4) Death by 60
Paralytic polio	-0.013	-0.006	-0.002	0.033
	[0.013]	[0.017]	[0.018]	[0.022]
Unskilled background	0.004	0.017	0.020	0.055**
	[0.013]	[0.017]	[0.019]	[0.023]
Mean, dept. var.	0.066	0.108	0.132	0.209
Observations	1,599	1,599	1,599	1,599

Notes: Robust standard errors in brackets. The sample includes all children admitted with non-paralytic or paralytic polio in 1952, except for the 50 paralytic polio patients for whom we observe an in-hospital death in the data. No merge to the 1970 Census (column 1) is interpreted conservatively as death by 1970. Columns 2-4 draw on information from the merge to the census and the administrative data (post 1980), as well as the death register starting in 1973. For further notes, see Table 3. $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$.

Table A.4: Age 50 Outcomes, Bounding Exercise. Administrative Data

	(1) Univ.Edu	(2) Employed	(3) Disab.Ins.	(4) Blue-collar Occ	(5) Wage Earnings
A. Baseline Results					
Paralytic polio	0.032**	-0.047*	0.079***	-0.055**	-3,863
	[0.016]	[0.027]	[0.021]	[0.026]	[12,193]
B. Impute Outcomes of Deceased as Least Favorable					
Paralytic polio	0.022	-0.090***	0.129***	0.033	-21,837*
	[0.014]	[0.026]	[0.024]	[0.025]	[11,369]
Mean, dept. var.	0.076	0.568	0.277	0.456	200,834
Observations	1,635	1,649	1,649	1,649	1,625
C. Impute Outcomes of Deceased as Most Favorable					
Paralytic polio	0.097***	-0.012	0.055***	-0.070***	14,230
	[0.021]	[0.023]	[0.018]	[0.020]	[11,045]
Mean, dept. var.	0.204	0.718	0.136	0.209	270,210
Observations	1,635	1,649	1,649	1,649	1,625

Notes: Robust standard errors in brackets. $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$. For further notes, see Table 3.

Table A.5: Skill Outcomes at Age 50, Bounding Exercise. Administrative Data

	A. Baseline Results				
	(1) Cognitive	(2) Brawn	(3) Spatial/Vision	(4) Dexterity	(5) Computer Skills
Paralytic polio	0.980	-7.949***	-6.873***	-4.408***	5.609***
	[1.704]	[1.648]	[1.607]	[1.702]	[1.710]
Mean, dept. var.	53.01	42.77	44.77	45.26	54.87
Observations	1265	1265	1265	1265	1265
	B. Impute Outcomes of Deceased as Least Favorable				
	(1) Cognitive	(2) Brawn	(3) Spatial/Vision	(4) Dexterity	(5) Computer Skills
Paralytic polio	-2.656	-9.574***	-8.914***	-6.918***	1.183
	[1.659]	[1.513]	[1.517]	[1.588]	[1.676]
Mean, dept. var.	46.03	37.45	39.12	39.54	47.59
Observations	1510	1510	1510	1510	1510
	C. Impute Outcomes of Deceased as Most Favorable				
	(1) Cognitive	(2) Brawn	(3) Spatial/Vision	(4) Dexterity	(5) Computer Skills
Paralytic polio	4.023**	-2.895*	-2.235	-0.239	7.862***
	[1.595]	[1.661]	[1.617]	[1.662]	[1.580]
Mean, dept. var.	59.01	50.43	52.10	52.52	60.57
Observations	1510	1510	1510	1510	1510

Notes: Robust standard errors in brackets. Imputing outcomes for all deceased as if they are working, at occupations that have skill requirements at the 10th or 90th percentile, respectively. $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$. For further notes, see Table 3.

B Factor Analysis for Occupational Descriptors

The administrative registers record occupations at a very detailed 6-digit level. We link these Danish codes to ISCO-88 4-digit codes. To characterize these almost 800 occupations succinctly and meaningfully, we use their task requirements in a range of domains. Drawing on O*NET, a database containing detailed occupational descriptors and skill requirements, we express each occupation's intensity in specific inputs.

O*NET, the Occupational Information Network, https://www.onetcenter.org was developed under the sponsorship of the US Dep. of Labor/Employment and Training Administration. It draws on information from the US labor market. Nevertheless, researchers apply it in other settings as well, since the work requirements are comparable in highly developed western countries, including Denmark. We draw on the following crosswalks to merge the ISCO-88 codes to O*NET's classification: The International Labor Organization (developer of ISCO codes) provides a crosswalk `http://www.ilo.org/public/english/bureau/stat/isco/isco08/` from ISCO-88 to ISCO-08, and the US Bureau of Labor Statistics offers a crosswalk `www.bls.gov/soc/ISCO_SOC_Crosswalk.xls` from ISCO-08 to SOC 2010 (Standard Occupational Classification), which leads to the O*NET classification through O*NET's own crosswalk. `http://www.onetcenter.org/taxonomy/2010/soc.html/2010_to_SOC_Crosswalk.xls`

We focus on O*NET's descriptions of worker abilities (part of worker characteristics), which are described as "enduring attributes of the individual that influence performance." O*NET lists the required *level* of a skill that is needed or required to perform the occupation, and its *importance*, on 52 abilities that cover cognitive as well as sensory, psychomotor, and physical abilities. We aggregate the descriptors in O*NET with confirmatory factor analysis on the level ratings, using the full Danish population of the birth cohorts in our analysis when they are 50 years old.

The occupational descriptors are produced with the following procedure:

1. Obtain the Danish population sample of 50-year-olds from the birth cohorts in our analysis sample, keep their Danish occupation codes. This sample will be used twice.

2. Generate a crosswalk from Danish occupation codes in the administrative registers to O*NET codes.

   (a) Connect Danish occupation codes to ISCO-88.

      i. The administrative registers record occupations at a very high level of aggregation (6-digit ISCO codes, Danish '88 version).

      ii. Use the first 4 digits of the Danish codes to use the higher level of aggregation in ISCO-88 4-digit codes. While the vast majority of all Danish 4-digit codes correspond exactly to ISCO-88, the Danish version contains some higher-order aggregation (3-digit codes) that do not have an official correspondence to ISCO-88 (14%).[22] To attribute an ISCO-88 to these occupations, we determine the most frequent 4-digit occupation that occurs in the population within the same 3-digit code. Merge the popuplation sample to the official ISCO-88 list to identify non-matches. Then tabulate the frequency to obtain the mode of 4-digit codes, and link the Danish 3-digit occupation to this empirical mode within the 3-digit group.

      iii. After attributing ISCO-88 codes to all Danish codes, collapse data on Danish code and ISCO-88 level to keep only the crosswalk.

[22] An example is Danish code 2110, "Work within physics, chemistry, astronomy, meteorology, geology, and geophysics,", where ISCO-88 lists 2111 "physicists and astronomers," 2112 "meteorologists," 2113 "Chemists," etc. Those lower-order categories also exist in the Danish classification.

(b) Connect ISCO-88 to ISCO-08 (from 2008, more recent than ISCO-88). The International Labor Organization (developer of ISCO codes) provides a crosswalk[23] from ISCO-88 to ISCO-08.

(c) Connect ISCO-08 to SOC 2010. The US Bureau of Labor Statistics offers a crosswalk[24] from ISCO-08 to SOC 2010 (Standard Occupational Classification)

(d) Connect to the O*NET classification through O*NET's own crosswalk.[25]

3. Read in the ability measures (levels) from O*NET (The Occupational Information Network, https://www.onetcenter.org)

4. Use the population sample to obtain a population distribution of O*NET measures, by merging the crosswalk to the population, then merging to the O*NET ability measures.

5. Perform exploratory factor analysis on the entire set of ability measures. We performed initial analyses on levels and importance measures either separately or jointly, and on the products of these two within type (example: one entry is given by the product of "Stamina, level" times "Stamina, importance"). Determine the number of factors to retain, with rules-of-thumb from scree plots and eigenvalues. Ultimately decided on using the levels only, and using a four-factor structure.

6. For the set of levels of all measures given by O*NET for abilities, retain 4 factors. Rotate the loadings obliquely using the promax rotation. We report the rotated factor loadings in Table B.1.

7. Predict scores on these factors, and collapse the data by occupation codes.

8. Merge the skill scores to the polio sample's occupations via the Danish occupation codes.

[23] `http://www.ilo.org/public/english/bureau/stat/isco/isco08/`

[24] `www.bls.gov/soc/ISCO_SOC_Crosswalk.xls`

[25] `http://www.onetcenter.org/taxonomy/2010/soc.html/2010_to_SOC_Crosswalk.xls`

Table B.1: Factor Loadings

	Cognitive	Brawn	Spatial/Vision	Dexterity
Oral Comprehension	0.867	-0.095	-0.142	-0.110
Written Comprehension	0.823	-0.232	-0.107	-0.066
Oral Expression	0.866	-0.078	-0.107	-0.195
Written Expression	0.808	-0.187	-0.064	-0.199
Fluency of Ideas	0.922	0.067	-0.094	-0.164
Originality	0.909	0.124	-0.078	-0.241
Problem Sensitivity	1.008	0.165	-0.121	-0.025
Deductive Reasoning	0.944	-0.051	-0.062	-0.042
Inductive Reasoning	0.965	0.030	-0.130	0.022
Information Ordering	0.922	-0.144	0.030	0.106
Category Flexibility	0.893	-0.138	-0.119	0.150
Mathematical Reasoning	0.814	-0.183	0.074	-0.010
Number Facility	0.800	-0.152	0.059	0.027
Memorization	0.860	-0.021	-0.027	-0.192
Speed of Closure	0.928	-0.045	0.109	0.022
Flexibility of Closure	0.872	-0.072	0.081	0.346
Perceptual Speed	0.663	-0.153	0.250	0.504
Spatial Orientation	-0.056	-0.005	1.005	-0.067
Visualization	0.581	0.115	0.232	0.419
Selective Attention	0.787	0.002	0.280	0.241
Time Sharing	0.802	0.322	0.292	-0.251
Arm-Hand Steadiness	-0.132	0.375	-0.072	0.715
Manual Dexterity	-0.282	0.241	0.036	0.704
Finger Dexterity	0.017	0.022	-0.101	0.977
Control Precision	-0.124	0.020	0.288	0.748
Multilimb Coordination	-0.157	0.419	0.243	0.435
Response Orientation	-0.032	0.249	0.470	0.408
Rate Control	-0.160	0.020	0.618	0.407
Reaction Time	-0.003	0.199	0.493	0.421
Wrist-Finger Speed	-0.352	-0.090	0.262	0.689
Speed of Limb Movement	-0.248	0.551	0.370	0.077
Static Strength	-0.179	0.649	0.177	0.224
Explosive Strength	0.282	0.649	-0.004	0.097
Dynamic Strength	-0.237	0.611	0.184	0.226
Trunk Strength	-0.150	0.860	0.049	0.010
Stamina	-0.190	0.814	0.111	0.041
Extent Flexibility	-0.308	0.646	0.022	0.263
Dynamic Flexibility	-0.477	0.395	0.153	0.052
Gross Body Coordination	-0.169	0.780	0.124	0.107
Gross Body Equilibrium	-0.041	0.680	0.234	0.141
Near Vision	0.650	-0.487	-0.119	0.419
Far Vision	0.633	0.252	0.423	-0.099
Visual Color Discrimination	0.428	0.288	0.065	0.577
Night Vision	-0.084	-0.094	1.085	-0.074
Peripheral Vision	-0.092	-0.047	1.097	-0.141
Depth Perception	0.049	0.221	0.454	0.420
Glare Sensitivity	-0.159	-0.045	0.976	0.003
Hearing Sensitivity	0.403	0.251	0.400	0.343
Auditory Attention	0.298	0.317	0.423	0.266
Sound Localization	-0.015	-0.018	1.034	-0.088
Speech Recognition	0.707	-0.091	-0.191	-0.280
Speech Clarity	0.781	0.003	-0.074	-0.401

Note: The factor loadings shown are rotated with an oblique promax rotation at power 3.