ORIGINAL ARTICLE

Long run impacts of birth defects on labor market outcomes: Evidence from oral clefts

George L. Wehby[1,2]*, Dorthe Almind Pedersen[3], Padmaja Ayyagari[4], Kaare Christensen[3]

[1]Department of Health Management and Policy, The University of Iowa, Iowa City, Iowa, USA.

[2]National Bureau of Economic Research, Cambridge, Massachusetts, USA.

[3]University of Southern Denmark, Odense, Denmark.

[4]Department of Economics, University of South Florida, Tampa, Florida, USA.

Abstract

We examine differences in employment and wages between individuals born with oral clefts, one of the most common birth defects worldwide, and their own unaffected siblings. Using unique population-based registry data that link data on being born with an oral cleft and administrative data on labor market outcomes during adulthood from Denmark and sibling comparisons, we find that individuals born with oral clefts are less likely to be employed and to have lower wages than their unaffected siblings. The effects are concentrated among individuals with cleft palate for whom employment and wage gaps are lower by up to 10% and 7%, respectively. There is no evidence of gaps for individuals born with cleft lip only. This finding suggests that long-term speech impairments or other impacts associated with cleft palate impose a disadvantage in the labor market and highlight the need for early interventions to address them.

Keywords

Oral clefts; labor market; birth defects

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Corresponding author:
Dr. George L. Wehby, Ph.D. Professor and Head, The John W. Colloton Chair, Department of Health Management and Policy, The University of Iowa, Research Associate, National Bureau of Economic Research, USA

Email: george-wehby@uiowa.edu;

Tel: 1- 319-384-3814.

Introduction

An extensive literature has shown that fetal health shocks affect long term outcomes such as health, educational attainment and labor market outcomes.[1] Studies have examined the impact of factors such as the 1918 influenza pandemic, iodine supplementation during pregnancy and low birth weight on various outcomes including years of schooling, physical disability, income, adult height and IQ.[2–10] A challenge facing this literature is that fetal health is likely to be correlated with family socioeconomic background and parental characteristics and other unobserved factors that also affect cognitive and non-cognitive outcomes later in life. In addition, few studies are able to identify the mechanisms through which childhood health impacts adult outcomes.

This study uses unique population-based data from Denmark and exploits plausibly exogenous variation in birth defects across siblings to identify the effect of these conditions on work and wages during adulthood. We focus on the occurrence of oral clefts (without other defects), one of the most common birth defects worldwide, that occur when a child's lip or palate do not form properly, for several reasons. Oral clefts occur very early during pregnancy, by the 9th week of gestation due a complex etiology involving genetic and environmental factors. Even though maternal factors early in pregnancy such as smoking and vitamin supplements may modify cleft risks in the population, genetic factors likely have the dominant effect, estimated to explain 70-90% of cleft risks.[11–13] Within families, genetic differences between siblings (which occur randomly) are likely the main reason for why one child has a cleft but not a sibling.

Although oral clefts are surgically repaired early in life (usually within the first year or two), they may impact the health and psychosocial wellbeing of affected individuals and require wide spectrum of medical, dental, speech, and behavioral interventions that may extend into adolescence and adulthood. There is evidence that oral clefts represent permanent fetal shocks to health capital accumulation that not only reduce health on average but also widen the spread among affected children compared to unaffected ones.[14] Therefore, studying the long-run effects of oral clefts as fetal health shocks on labor market outcomes contributes to the fetal-origin literature.

There are three main types of oral clefts: cleft lip alone, cleft palate alone, and cleft lip with cleft palate. We use information on whether or not an individual is born with an oral cleft and the type of cleft they are born with to identify effects on labor outcomes. Cleft lip primarily affects facial appearance (including after surgery through surgical scarring and facial asymmetries) while cleft palate primarily affects speech (even with surgical repair and speech therapy). We use information on the type of oral cleft (lip only, palate only, and lip with palate) that a person has to distinguish between mechanisms that are possibly related to the effects of speech problems versus facial appearances. We estimate the effects of oral clefts on employment and wages by comparing affected individuals to their unaffected siblings (i.e. a sibling fixed effect research design) to account for unobserved family-level variables correlated with both the occurrence of clefts and with work or wages.[a] We find that being born with an oral cleft decreases the probability of employment by nearly 4 percentage-points (nearly 5% of mean) and wages among earners by nearly 5%. These gaps are more pronounced among individuals with cleft palate but differences for individuals with cleft lip only are small and statistically insignificant. Differences in educational attainment between affected individuals and their siblings only explain a small portion of the gaps.

Background

Clefts of the lip and palate are one of the most common birth defects, affecting about 1 per 700 live births on average with varying prevalence by ancestry, socioeconomic status, and gender (more common among males)[b].[15] Oral clefts occur by the 9th week of gestation due to a complex etiology involving genetic and environmental factors.[16–20] The overall genetic heritability is estimated to be at least 70% with some estimates as high as 90%,[11–13] and several genetic variants have been identified that are considered to unequivocally confer susceptibility to oral clefts.[17,21,22] However, the specific genes identified so far explain only a limited percent of the prevalence of oral clefts. A few behavioral/environment factors have also been reported to influence the risk including smoking,[20,23,24] excessive alcohol consumption[25], obesity [26], and folic acid and multivitamin use.[27]

Later in childhood, oral clefts have been associated with a higher rate of certain psychosocial and behavioral problems such as inattention/hyperactivity, increased anxiety/depression and lower self-esteem and problems in social interactions and adjustment.[28–32] Several factors have been suggested to contribute to the higher risk for behavioral problems including speech problems in the case of cleft palate and dissatisfaction with facial appearance in the case of cleft lip [33–35], which may occur due to facial asymmetry, surgical scarring, and dental issues. The number of cleft repair surgeries has also been associated with increased depression/anxiety and somatic symptoms.[31] Some of these behavioral and social interaction problems may extend to adolescence.[28,36]

In addition to the psychosocial outcomes, several studies have reported associations with mental development and cognitive skills. A greater risk for mental development problems has been reported during infancy. [37,38] A study also reported children and adolescents with oral clefts to have lower verbal and memory skills than unaffected ones.[39] Others have reported increased learning disabilities among children with oral clefts.[40,41] Population-based studies of academic achievement from Iowa and North Carolina in the United States reported that children born with oral clefts had lower test scores when compared with unaffected peers[42–44] although not when compared to siblings.[45] A study from Denmark showed lower scores and rates of attaining the 9th grade Danish standardized exam for adolescents born with cleft palate compared to a 5% sample of the same birth cohort but no differences for cleft lip and cleft lip with palate.[46] A study from Norway reported no significant differences in attaining intermediate education at age 21 or university education at age 25 for all three cleft types.[47] Another study from Norway found overall comparable grades when completing middle school

for children with cleft lip only and cleft lip with cleft palate compared to children without clefts and slightly lower grades for children with cleft palate only.[48] In contrast, studies from Sweden reported lower achievement outcomes with all three cleft types.[49,50]

In the long term, oral clefts also influence the health and quality of life of affected individuals. Some studies reported reductions in wellbeing and quality of life,[51] and increase in social anxiety,[52,53] mental health hospitalizations,[54,32] and mortality and suicide risks.[55] Also, hospitalizations are increased through middle age adulthood.[56] Overall, children with oral clefts use more health services than their unaffected siblings including hospitalizations and medication use.[57] In settings without universal, comprehensive access to healthcare services, barriers and disparities in children's access to care and utilization of health services have been reported.[59]

Despite the large literature on the effects of oral clefts on health and psychosocial wellbeing, little is known about whether oral clefts affect long-term economic productivity. Specifically, there have been no studies using large population-based samples that evaluate the effects on employment and earnings. A small number of studies using small samples (less than 300 affected individuals) have compared the employment and income of affected individuals to unaffected ones. These studies did not report major differences in employment, but two reported lower income/economic performance.[60,61] However, these studies used basic descriptive methods and selective samples and as a result, their results may be biased and not generalizable. Therefore, a study using a robust design and large population-based sample is needed to identify the effects of oral clefts on labor-market outcomes.

Conceptual Framework

There are several pathways through which oral clefts as fetal health shocks with "permanent" and lifelong lasting consequences may affect work status or wages, consistent with the framework of fetal-origin hypothesis with shocks in-utero development having persistent effects on health that last into adulthood. First, oral clefts could affect adult labor market outcomes through physical health. Oral clefts represent a fetal health shock associated with lower birth weight;[62] lower birth weight has been linked to reduced earnings and educational among adults.[4] Early in life, oral clefts also result in feeding problems,[63] which have also been linked to reduced education and disability risks.[64,14] As discussed above, hospitalizations are more common among individuals with oral clefts through mid-adulthood.[56,58]

Second, oral clefts may affect labor market outcomes through reducing educational achievement and attainment[44,49] and affecting language and memory skills[39,41] as discussed above. Children with cleft palate are at risk of speech problems; speech patterns have been shown to affect schooling and earnings.[65]

Third, oral clefts might affect factors such as psychosocial wellbeing and the development of non-cognitive skills as described above, which have been shown to impact adult labor market outcomes.[66] Individuals with oral clefts may fare less favorably in employment than unaffected individuals if there is a long-term effect on psychosocial wellbeing due to dissatisfaction with facial appearance and speech problems. While facial scarring and asymmetry can be subtle in many individuals with oral clefts, they are more visible in some cases depending on cleft severity and the quantity and quality of surgical and dental treatments. Oral cleft effects on self-confidence, social communication and interaction skills may influence individual motivation to seek employment and productivity and job choice.

Earning differences may also occur through differences in employers' perceptions of human capital for persons with and without oral clefts. If employers discriminate in hiring or in compensating individuals with oral clefts based on perceived attractiveness (partly influenced by surgical scarring or facial asymmetry) or on speech problems, this would contribute to an earning gap between affected and unaffected individuals. Existing literature has generally shown that individuals perceived to be more attractive earn more than less attractive individuals.[67–71] Some studies point mainly to increased self-confidence and communication/social skills and to employer discrimination as contributors to earning differences,[70–71] although other studies suggest an effect of attractiveness on human capital formation earlier in life including during adolescence.[72]

Fourth, oral clefts increase the need for healthcare treatments and may reduce family finances and parental investments in children's development. Initial cleft repair surgeries are usually completed within the first few months of life for cleft lip and within the first two years of life for cleft palate, with multiple surgeries needed in several cases. Additional surgeries maybe needed later in childhood or adolescence. This increases hospital use and costs for affected children.[51] Hospitalization days increase by more than 200% during the first 9 years of life in Denmark[56] and hospitalization costs are 8 times higher for affected children during the first 10 years of life in the United States.[57] However, an effect on family finances is less of a concern for our study using Danish data since all cleft repair surgeries, dental treatments, and speech therapy services are covered in public health insurance system.

Data

We employ unique individual-level data on virtually the entire population of individuals born with oral clefts between 1960 and 1980 and living in Denmark through 2005 and their unaffected siblings. The data are obtained from several national and population-based registries in Denmark provided to researchers through Statistics Denmark, a governmental agency within the Ministry of Economic and Business Affairs. This data source includes several administrative datasets that can be linked using a unique personal identification number, which is available for each individual in Denmark who was alive on April 1, 1968 or born thereafter. Our data comes from three main registries: the Danish Facial Cleft Registry, the Danish Civil Registration System, and the Integrated Database for Labor Market Research. Appendix A provides detailed information on each registry and access to the data through *Statistics Denmark*.

Sample Selection: We use data from 1985 through 2005 and restrict our sample to individuals born between 1960 and 1980. 1960 is the first birth year when virtually all individuals can be accurately linked to their siblings; before 1960 family linkages are not possible for the entire sample. 1980 is chosen as the last birth year so that the youngest individual in the sample will be 25 by 2005, which is the last year for which data linkage had been approved and completed for this study. We consider 25 years to be a reasonable minimum age to study earnings since most individuals would have completed their schooling by then. For example, in 2023 in Denmark, 3.2% of adults aged 25-45 were still enrolled in higher education.[c] We only include individuals with oral clefts who have no other birth defects in order to isolate the effects of oral clefts.[d] Since our estimation method relies on sibling differences, we further restrict our sample to individuals with oral clefts who have at least one full and biological unaffected sibling and exclude non-biological and half-siblings.

Labor Market Outcomes: We evaluate two labor market outcomes. The first is an indicator for being employed or self-employed at the end of November, recorded in the Integrated Database for Labor Market Research (described in detail in Appendix A). The second outcome is annual wages from work-for-pay but not income from self-employment (unavailable for our study), obtained from the Central Database on Salary Information, a registry that records wages for taxing purposes (details in Appendix A). Since the labor outcome data for each individual are observed annually between 1980 and 2005, we construct a panel dataset with person-year as the unity of analysis. A very small number of observations reporting being employed but having 0 wages are excluded. The analytical sample includes a total of 4,270 unique individuals who fit the inclusion criteria and contribute up to 48,908 person-year observations (1,713 individuals with oral clefts contributing 18,830 person-years and 2,557 unaffected siblings contributing 30,078 person-years).

Empirical Model

As mentioned above, identifying the effects of oral clefts on labor market outcomes is complicated by potential unobserved variables correlated with both the risk of being born with an oral cleft and future human capital. Even though a large proportion of the variation in oral cleft risk is thought to be genetically influenced, maternal characteristics during pregnancy such as smoking, alcohol, body weight, nutrition, and socioeconomic status may also influence this risk.

To identify the effects of oral clefts on labor market outcomes we use a sibling fixed effects model which compares affected individuals to their unaffected siblings.[e] The key identification assumption is that all relevant unobserved factors related to both oral cleft risks and the labor

market outcomes of interest are shared between full siblings. This is a reasonable assumption to account for family-level background characteristics such as socioeconomic status and maternal preferences and behaviors, since these characteristics are not expected to change significantly between pregnancies for the majority of cases. We also account for observable child-specific characteristics including year of birth fixed effects, and indicators for maternal and paternal age at child birth in the model. In additional models, we explore controlling for birth order and county of birth and find similar results.

To estimate the impact of oral clefts on employment, we use a siblings fixed effects model of the form:

$$WORK_{it} = \alpha_1 + \alpha_2 CLEFT_i + X'_{it}\alpha_3 + \tau_t + \gamma_f + \varepsilon_{it} \quad (1)$$

Where, *WORK*, is a binary indicator for whether or not person *i* is employed or self-employed at the end of November in year *t*. Alternatively, we focus on employment (work for pay) versus unemployed (excluding self-employed individuals from the model) to disentangle work status. *CLEFT* is a binary indicator for whether or not individual *i* has an oral cleft, or alternatively, indicators for cleft type – cleft lip alone, cleft lip and palate, cleft palate alone, with the reference category being no cleft. *X* is a vector of socio-demographic variables which includes dummies for gender, and maternal and paternal ages at child birth. γ_t represents year fixed effects and γ_f represents family fixed effects.

Next, we estimate a similar siblings fixed effects model for wages:

$$WAGES_{it} = \beta_1 + \beta_2 CLEFT_i + X'_{it}\beta_3 + \zeta_t + \delta_f + u_{it} \quad (2)$$

The dependent variable in equation (2) measures wages from employment (work-for-pay) but not self-employment (data on income from self-employment were unavailable to us). Independent variables are as described above. We first estimate equation (2) for total wages including those with zero earnings from work-for-pay. In another model, we focus on individuals with non-zero wages.

We estimate the regression models using OLS. Given that there are multiple observations per individual over time, we use a Huber-type estimator of the standard errors that clusters the variance-covariance matrix at the individual level.[73]

In addition to the basic specifications described above, we estimate additional specifications in order to examine how human capital attainment may explain the effects of oral clefts on work or wages. We do so by adding indicators for educational attainment (at year t) measured on the following schooling categories: basic, high school/upper secondary, vocational, short-term higher education, intermediate-term higher education, bachelor, and masters/PhD.

Results

Table 1 shows a descriptive comparison of employment, wages, educational attainment between individuals with oral clefts and the sample of unaffected siblings. We note that this is not a comparison to own siblings but to the total sample of siblings and therefore does not account for any confounders. One such confounder is gender; 64% of the sample with oral clefts are males compared to 52% of unaffected siblings. Rate of employment or self-employment is higher among unaffected siblings by nearly 2 percentage-points. In contrast, average wages including unemployed individuals are comparable between the two groups; wages among employed individuals are slightly higher on average among individuals with oral clefts. The distribution of educational attainment is comparable between the two groups.

In Table 2, we show the regression estimates of differences in employment and wages between individuals with oral clefts and their own siblings estimated from the regression models described above. We find that individuals born with oral clefts are less likely to work than their unaffected siblings by 4 percentage-points. This difference is entirely due to reduced employment rather than self-employment and is nearly 4.8% of sample employment rate. In terms of wages, individuals with oral clefts have lower earnings than their unaffected siblings by 11,332 kroners (K) or by 6.3% of mean earnings when including unemployed

individuals and by 9,505 K (4.6% of mean) when focusing on earners. Differences in educational attainment explains little of the employment and wage gaps, including by about 10% for employment and 1.3% for wages among earners.

Table 1. Descriptive Statistics

Variable	Individuals with oral clefts	Siblings without clefts
Employed or self-employed in November (%)	81.3	83.2
Employed in November excluding self-employed	80.6%	82.3
Wages including 0 wages (Kroners (DKK)) – Mean	179585.3	179477.1
Wages excluding 0 wages (Kroners (DKK)) – Mean	208008.3	206341.7
Males %	63.7	52.0
Education %		
Basic School	30.5	29.7
High school/ upper secondary	8.6	8.9
Vocational school	37.7	39.3
Short-term higher education	5.8	4.4
Intermediate-term higher education	10.2	11.2
Bachelor	2.0	2.2
Masters and/or PhD	5.3	4.4
Unique individuals	1,713	2,557
Person-year observations	18,830	30,078

Note: There are 598 unique individuals with cleft lip only, 702 unique individuals with cleft lip with palate, and 413 unique individuals with cleft palate only.

Table 2. Effects of Oral Clefts on Work Status and Wages Comparing Affected and Unaffected Siblings

Outcomes	(1)	(2)	Sample Mean
Employed or Self-Employed versus no work	-0.040***	-0.035***	0.824
	(0.0088)	(0.0084)	
Employed versus no work (excluding self-employed)	-0.039***	-0.035***	0.817
	(0.0090)	(0.0087)	
Wages (including 0 wages)	-11332.1***	-9717.5***	179518.8
	(3143.7)	(2956.6)	
Wages (excluding 0 wages)	-9504.9***	-9377.1***	206,980.4
	(2758.3)	(2606.1)	
Model controls for educational attainment	No	Yes	

Notes: All models control for family fixed effects, sex, year of birth, year of labor outcome, and maternal and paternal age at child's birth. Standard errors are in parentheses and clustered at the individual level to account for correlation in errors across individuals over time. Each estimate represents the difference in outcomes between individuals with oral clefts and their siblings. Sample sizes range from 41,227 to 48,908 observations. * p < 0.1, ** p < 0.05, *** p < 0.01

Next, we show differences between individuals with oral clefts and their siblings separately by cleft type estimated from the same regression specification (Table 3). We find no evidence of gaps between individuals with cleft lip only and siblings; differences in employment and wages are very small and statistically insignificant. In contrast, we find reduced employment and wages for individuals with cleft lip and palate or cleft palate only. The gap in employment is largest for individuals with cleft palate only at 8.2 percentage-points (10% of mean) and nearly twice the gap for individuals with cleft lip and palate. Wage differentials among earners compared to unaffected siblings are relatively close for cleft palate only and cleft lip with palate, including 15,434 K (7.5% of mean) and 14,061 K (6.8% of mean). Differences in education attainment explain nearly 15% of the employment gaps and 9-11% of the wage gap among earners.

Table 3. Effects of Oral Cleft Types on Work Status and Wages Comparing Affected and Unaffected Siblings

Outcomes	Cleft lip only	Cleft lip with palate	Cleft palate only	Cleft lip only	Cleft lip with palate	Cleft palate only
Employed or Self-Employed versus no work	-0.0048 (0.013)	-0.042*** (0.013)	-0.086*** (0.020)	-0.0074 (0.013)	-0.035*** (0.013)	-0.072*** (0.019)
Employed versus no work (excluding self-employed)	-0.0046 (0.014)	-0.041*** (0.014)	-0.084*** (0.020)	-0.0082 (0.014)	-0.035*** (0.013)	-0.071*** (0.019)
Wages (including 0 wages)	433.8 (5170.3)	-15121.7*** (4856.6)	-21589.2*** (6258.4)	-1243.6 (5005.5)	-12360.9*** (4541.5)	-17330.4*** (5866.1)
Wages (excluding 0 wages)	-194.6 (4410.2)	-14061.2*** (4238.3)	-15434.0*** (5698.8)	-2724.4 (4227.6)	-12435.2*** (4015.4)	-13982.0*** (5314.8)
Model controls for educational attainment	No	No	No	Yes	Yes	Yes

Notes: All models control for family fixed effects, sex, year of birth, year of labor outcome, and maternal and paternal age at child's birth. Standard errors are in parentheses and clustered at the individual level to account for correlation in errors across individuals over time. Each estimate represents the difference in outcomes between individuals with oral clefts and their siblings. Sample sizes range from 41,227 to 48,908 observations. * p < 0.1, ** p < 0.05, *** p < 0.01

Conclusion

Our study is the first to investigate the consequences of being born with oral clefts for employment and wages during adulthood using large samples and within-family comparisons. We find that individuals born with oral clefts are less likely to be employed and have lower wages as adults compared to their own siblings. Differences in educational attainment explain only a small portion of the gaps (up to 15%), indicating that other factors that we cannot measure in this study such as employer-discrimination in wage rates, differences in human capital beyond educational attainment, and psychosocial effects of oral clefts on self-esteem and social communication skills play a role. Further work is needed to evaluate the effects of such factors in the observed employment and wage gaps.

Individuals with cleft palate (with or without cleft lip) experience gaps in employment and wages but not individuals with cleft lip only. This finding suggests that speech impairments associated with oral clefts impose a disadvantage in the labor market and that any residual effects on facial appearance such as due to surgical scarring appear to have no impact, at least in Denmark. There might be less awareness about less visible problems such as speech impairments caused by cleft palate (compared to surgical scarring in the case of cleft lip) and so, such defects might garner less support from employers. Individuals with speech problems might also find it harder to communicate or interact socially which could affect employment and wages. Individuals with cleft palate only have twice the gap in employment as those with cleft lip with palate (compared to siblings). This result may seem counterintuitive since individuals with cleft lip with cleft palate are expected to have similar speech problems on average as those with cleft palate alone. One possible reason is that there are likely more individuals with unidentified genetic disorders or birth defects among individuals with cleft palate than those with cleft lip with palate. Even though we only include individuals who are thought to have oral clefts without other birth defects or syndromes, it is possible that these conditions were diagnosed later in life and therefore not recorded in the Danish Facial Cleft Registry from which data on cleft status are obtained. As noted above, nearly half of individuals with cleft palate only occur with other birth defects or genetic disorders compared to only 30% of individuals with cleft lip (with or without palate). Therefore, the chance of underdiagnosis is higher for cleft palate only. Another potential factor is the lower rate of surgical repair for cleft palate only. We did not evaluate surgical repair in this study. However, another study from Denmark with a later-born cohort from 1986-1990 reported that 100%, 97.6% of individuals with cleft lip only, and 75.4% of

individuals born with cleft lip with cleft palate, cleft lip only, and cleft palate only respectively had received at least one cleft repair operation.[46] It is possible that the lower surgical repair for cleft palate only, possibly in cases of submucous cleft palate, may contribute to the more pronounced effects among individuals with cleft palate only. Future work considering type, timeliness, and quality of surgical interventions can examine effects on long-term socioeconomic outcomes.

The study findings suggest that shocks to fetal development that leave a "permanent mark" on individual's speech such as cleft palate reduce economic achievement in the long-run. Ensuring access to effective speech treatments early in life appears to be essential to addressing these gaps. Identifying the pathways through which the gaps develop and their timing is also needed for developing interventions and policies to eliminate these negative consequences. Our results suggest that focusing only on improving educational attainment would only minimally reduce these gaps, highlighting the need to understand and address other sources such as employer responses, communication skills, and psychosocial status.

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Endnote

[a]As mentioned above, oral clefts and earnings may be non-causally related due to parental factors that are common to both. For example, maternal smoking during pregnancy which is associated with an increased risk of oral clefts has also been shown to reduce infant neurodevelopment, an important predictor of long-term human capital attainment.[74] Other prenatal factors, such as lower socioeconomic status, which has important effects on early child development[75] and future human capital have also been shown to be related to oral clefts.[76,77] Prevalence varies by race and is typically highest among Native/Asian ancestries, intermediate for Caucasian/European populations, and lowest for African ancestry.[15]

[b]This estimate is consistent with estimates on incidence in Denmark.[78]

[c]Statistics Denmark. Higher education status of adults. https://www.dst.dk/en/Statistik/emner/uddannelse-og-forskning/befolkningens-uddannelsesstatus/voksnes-status-paa-videregaaende-uddannelser.

[d]About 70% of cleft lip with/without palate and 50% of cleft palate only occur alone without other birth defects or genetic disorders and are referred to as isolated forms.[79–82] The remaining cases (which we do not analyze in this study) occur with other birth defects or as part of syndromes and are referred to as non-isolated forms. We only study isolated forms.

[e]The study adds to a relatively small literature that incorporates sibling comparisons in relatively non-small samples of individuals with oral clefts (examples of other studies incorporating such comparisons are Collett et al, 2014, Pedersen et al, 2015, and Wydick et al, 2021).[45,58,83]

Appendix A

This Statistics Denmark administers researchers' access to the data and ensures maintenance of data confidentiality and anonymity by including several controls over the data use including that data is only accessible at designated research institutions within Denmark (in our case at the University of Southern Denmark) through secure virtual private network (VPN) connection and that the individual-level data always resides on Statistics Denmark servers. Multi-registry individual-level data from Statistics Denmark have been used in several studies and are of high quality, partly because much of the data is collected for administrative purposes and is not affected as much by reporting biases and measurement errors as self-report survey data.[11,56,84]

Oral Cleft Information. The Danish Facial Cleft Registry includes virtually all (99%) individuals born with oral clefts in Denmark since 1936.11 Since the mid-1930s, all cleft-repair surgeries have been centralized at two hospitals in Denmark. The registry identifies affected individuals from a systematic and continuous review of patient records from these two hospitals. Denmark has a national government funded health care system that covers all cleft-repair surgeries, so virtually all oral clefts are repaired at these two hospitals. In addition, the registry also identifies affected individuals from reviewing the records of the National Institute for Defects of Speech to which all health professionals (including midwives)

are required to report any cases of oral clefts that they provide care to. The registry includes detailed data on all the malformations that individuals with oral clefts have, including cleft type, presence of other birth defects, and syndromes.

Sibling Information. We use data from the Central Person Registry in order to link the identified individuals with oral clefts to their unaffected full biological siblings. This registry provides information on date and place of birth and parents, which enables identifying full siblings. All individuals born in 1969 or later can be matched to their parents, while virtually all (about 98%) of those born in 1960-1968 can be matched. However, matching rates are much lower for individuals born in earlier years. The Central Person registry also has information on marital status, and current residence address which are updated with each change while retaining the old information, allowing construction of time-varying variables.

Labor Market Information: The last data source we employ is the Integrated Database for Labor Market Research, which is a research-oriented database that includes data on employment, income, education, and demographics from several other registries. The employment data are derived from several registries that record the main and secondary jobs that income-tax payers held at the end of November during each year. The income data are obtained from multiple sources, including a registry of employer-reported employee wages and pensions for taxing purposes (The Central Database on Salary Information) and Registry of Income Statistics which provides information on other income sources. Together, these databases allow for measuring earnings/wages per year. The education data are obtained from the Register of Education and Training Statistics which records recent educational attainment and type (including general versus vocational training). The dataset includes data on marital status and cohabitation, which is derived from the Central Person Registry through the Registry of Population Statistics. All measures are regularly updated (at least on an annual basis), allowing us to construct a panel dataset.

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