IJTMGH International Journal of Travel Medicine and Global Health

Int J Travel Med Glob Health. 2022 Feb;10(1):16-23
http://ijtmgh.com

doi 10.34172/ijtmgh.2022.04

Original Article Open Access

Developmental Cost of Being Asian but Living in the United States: Diminished Returns of Household Income on Cortical Surface Area in 9-10 Year Old Children

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Received September 3, 2021; **Accepted** December 13, 2021; **Online Published** February 16, 2022

Abstract

Introduction: While socioeconomic status (SES) indicators such as household income are known to be associated with larger cortical surface area, recent research on Marginalization-related Diminished Returns (MDRs) suggests that family SES indicators such as household income may have weaker effects on brain function and structure for non-White (marginalized) than White (privileged) families: a pattern that reflects structural and societal inequalities deeply intertwined into the United States social fabric.

Methods: This is a cross-sectional study that used baseline data from the Adolescent Brain Cognitive Development (ABCD) study. Data was collected between 2016 and 2018. Overall, 6039 9–10-year-old children entered our analysis. The independent variable was household income. The moderator was race. The primary outcome was the overall cortical surface area. Age, sex, and family structure were the covariates. We used mixed effects regression models that adjusted for data analysis because ABCD data is nested into families, centers, and US states.

Results: While high household income was associated with larger cortical surface area, this effect was weaker for Asian than non-Hispanic White children. This racial heterogeneity in the effects of household income on cortical surface area was documented by a statistically significant interaction between race and household income on cortical surface area.

Conclusion: For American children, household income does not similarly correlate with cortical surface area of diverse racial groups. Brain development in the US is not solely a function of SES (availability of resources) but also how social groups are racialized and treated in the society. In the US, race, as a proxy of racism, limits how much SES can affect brain structures such as cerebral cortex. Due to racialization, segregation, discrimination, and marginalization, racial minority children may experience weaker effects of SES. Structural inequalities should be addressed to equalize the return of SES resources across racially diverse families.

Keywords: Immigration, Health, Brain Development

Citation: Assari S, Lee A. Developmental cost of being asian but living in the united states: diminished returns of household income on cortical surface area in 9-10 year old children. Int J Travel Med Glob Health. 2022;10(1):16-23. doi:10.34172/ijtmgh.2022.04.

Introduction

The cerebral cortex, a primary component of the cerebrum, plays a significant role in many fundamental brain processes.[1] The four lobes of the cerebral cortex (frontal, parietal, occipital, temporal) are involved in functions including prospective and semantic memory, speech and language, decision making, movement control, and sensory processes such as vision and hearing.[1] The cerebral cortex thus has a central responsibility in the execution of basic human functions, and its development has wide implications for individuals' emotion, behavior, and health.[1]

The development of the cortex is under the influence of a large array of social and environmental factors.[2] A wide range of environmental factors influences cortical development. High socioeconomic status (SES), healthy diet, physical activity, and enriched social environment are positively associated with cortical development.[3] On the other hand, low SES, stressors, toxins, and negative environmental factors can lead to adverse effects on cortical development. Household income during childhood, one of major SES factors, has been shown to greatly influence neurological development including that of the cerebral cortex.[4,5] More specifically, children with lower SES and higher exposed to stressors and maltreatment have a smaller cortical surface area.[4,5]

Cortical development can be measured in many ways, but it is commonly represented through the surface area of the cortex.[5] Cortical surface area has been regarded as an indicator of overall brain and cognitive development.[5] Previous studies have highlighted that significant increases in cortical surface area strongly coincide with major, age-related development of the frontal, temporal, and parietal associative cortices.[6] Individuals born with very low birth weights have reduced cortical surface areas and cognitive function in comparison to those born at normal weights, illustrating the role of cortical surface areas to influence cognitive function.[5] Neurological disorders also lead to individuals experiencing alterations in cortical surface areas: While post-traumatic stress disorder (PTSD) and attention deficit hyperactive disorder (ADHD) are associated with reduced surface areas, autism is associated with surface area overgrowth.[5,7,8]

The brain development that occurs during childhood years is very significant and can have a large influence on one's future cortical surface area.[9,10] Specifically, a previous study found a strong, positive, linear relationship between cortical surface area and age up until 12 years: however, after this point, the change in cortical surface area might be far less pronounced, indicating that a significant portion of cortical development occurs during childhood and pre-teen years.[9] This phenomenon has many important implications: since significant cortical development occurs during childhood, the environmental factors that children are surrounded by are key determinants in their long-term cortical development and cortical surface area.

The environmental factor this paper will focus upon is household income, one of major SES indicators. Often used in combination with occupation and education, income is a measure of social standing, economic status, and social affluence.[11] As aforementioned, income has already previously been shown to impact cortical development: children growing up in families with lower income often experience weakened cognitive and emotional development as well as less linguistic and cognitive stimulation.[11,12] For instance, children from families of low SES have been shown to have poorer nutrition and lower levels of math skills at an entrance kindergarten level than those of higher SES.[3]

However, SES has varying effect on different population groups, especially among children of different racial and ethnic groups. For instance, Black and Hispanic children experience a higher burden of poverty and low SES in comparison to non-Hispanic White children.[13] Low SES indicators such as poverty, economic hardship, and low income predispose Black and Hispanic children to experiencing in greater magnitude of adversities than other groups. High levels of stress, reduced capacity of supportive parenting, and disrupted marital bonds-all of which adversely contribute to psychological distress in children and reduced brain surface areas.[13] The concept of marginalization-related diminished returns, also called minorities' diminished returns (MDRs), is evident within the aforementioned examples. Specifically, MDRs refer to the phenomenon that minorities experience fewer health benefits from higher SES in comparison to those of the majority group; likewise, minorities will experience greater health consequences from lower SES.[14] The examples of MDRs as aforementioned are more due to societal rather than biological factors: due to discrimination within society and economic disparities, Black children are in turn more likely to experience low SES and their consequences.[15]

While the differences in cortical surface area between Black children and non-Hispanic White children as an effect of household income during childhood have been relatively well documented and explored, there have been less investigations into the relationship between household income during childhood and the cortical surface area of Asian children in comparison to non-Hispanic White children.

Asian Americans are often described as a model minority for their apparent success in the US society: in 2019 they had the highest median income and the highest percentage of education across any minority group, with a median income of $85,800 and an approximate 58.1% holding a bachelor's degree or higher.[16,17] As a result of this appearance of overall economic success, there have been very few scientific investigations and research into Asian children brain development as a result of marginalization, racism, and discrimination within American society.[18] For instance, since 1992, only 0.17% of funds from the National Institutes of Health has been allocated to projects focused on Asian Americans in comparison to the 6% of the US population that Asian Americans make up.[18]

Despite the problematic notion of Asian Americans as a model minority all relatively prosperous in society, Asian Americans are not free of experiencing racial discrimination or economic hardships as a result of discrimination in the US. For instance, hate crimes against Asians in the US during the COVID-19 pandemic increased by 149% in 2020.[18] Although they earn the highest median income, Asian Americans had the highest income gap across any racial group in 2018, with Burmese Americans earning an average of $44,400 annually in comparison to the $85,800 average.[17,19] Highly educated Asian Americans had higher unemployment rates than highly educated White people, suggesting that racial bias plays a factor in Asians having more difficulty finding employment in comparison to White people.[20] Asian Americans and Pacific Islanders have had the highest rates of long term unemployment among minorities as a result of the pandemic, and similarly, Asian owned businesses have experienced the consequences of the pandemic on the labor market the most deeply, with a 17% decline in Asian entrepreneurship in comparison to non-Hispanic White people.[21] Anecdotal evidence suggests that this strong increase in Asian American economic hardship is due to racialized blaming and anti-Asian sentiments.[22] Although these economic hardships and impacts of discrimination became additionally clear this past year, it is evident that racial discrimination against Asians has always existed, with the pandemic merely exacerbating it.

From a health perspective, although it is unclear whether effects of the MDRs phenomenon impact Asians as much as they do Black or Hispanic people, previous studies have also shown that Asians are not immune to the effects of the MDRs phenomenon. For instance, results from a previous study that examined whether income has an effect on smoking status suggest that Chinese Americans experience fewer protective effects from income against tobacco use in comparison to European Americans.[23] Likewise, in comparison to non-Hispanic White children, Asian American children experience less benefits on cognitive function as measured by reading ability from higher parental educational attainment.[24] Although many Asian Americans are better educated and have higher incomes in comparison to other minorities, it is evident they are not free from experiencing MDRs.

The objective of this paper is to investigate the differences in cortical surface area between Asian and non-Hispanic White children aged 9 to 10 years old across different household income groups. Our hypothesis is that compared to low-income families, high income White children show some gain in their cortical surface area, however, this gain is smaller for Asian than White children.

Methods

Our study utilized data from the waive one of the Adolescent Brain Cognitive Development (ABCD) study. The ABCD is a comprehensive study of the brains of 9 to 10 year old American children from a wide variety of backgrounds including diverse race/ethnic and SES.[25-30] ABCD data is representative of participants enrolled in the study from 2016-2018 across 21 ABCD sites from the following 15 states: Maryland, California, Colorado, Connecticut, Florida, Michigan, Minnesota, Missouri, New York, Oklahoma, Oregon, Pennsylvania, South Carolina, Utah, Vermont, Virginia, and Wisconsin. Although this dataset includes participants from a relatively large variety of states, ABCD data is not nationally representative or completely generalizable to the US population of youth.[31] However, measures and strategies have been taken by ABCD to increase its generalizability.[31]

ABCD data was collected primarily within school and educational settings. However, a portion of participant recruitment occurred in local community organizations rather than school contexts in order to include a larger portion of non-White participants.[31] Therefore, consideration must be given to these different sampling strategies when comparing specific data representing different ethnic groups in the ABCD data. However, it is important to note that previous MDRs studies have been supported by over 100 local and national papers with a variety of different sampling designs; therefore, variance in sampling design has not shown to have significant interference in MDRs studies.[32]

Measures

This study utilized demographic (age, sex, family structure), race/ethnicity, SES (household income), and sMRI data. The overall cortical surface area was the sMRI indicator.[24]

Race: Rather than as a fixed definition in relation to genetics or biological differences, this study defined race as a social construct. In this sense, race is representative of social implications such as racial discrimination, adversity, and living conditions rather than a biological factor.

Income: Income was a 3-level categorical variable within this study, the following categories of annual income used: less than $50,000 (reference group), between $50,000 and $100,000, and greater than $100,000. Parents of the children participating in the study were specifically asked, „What is your total combined highest income for the past 12 months? This should include income (before taxes and deductions) from all sources, wages, rent from properties, social security, disability and veteran's benefits, unemployment benefits, workman.“

Scanning Protocol

This study only utilized structural neuroimaging data (sMRI) from the available ABCD data. A complete description of imaging and processing procedures can be found elsewhere.[31] In summary, structural MRI data was collected through performing MRIs at 21 sites in the United States, with a standardized protocol for imaging acquisition, processing, reconstruction, and quality control used. Likewise, all results were screened for incidental findings by a neuroradiologist. The ABCD team achieved full-brain coverage with across their data through the following parameters: isotropic voxel resolution of 1 × 1 × 1 × mm, 256 × 256 matrices, flip angle of 8°, an inversion delay of 1060 milliseconds, 176 to 225 sections, the field of view of 256 × 240 to 256, the field of view phase of 93.75% to 100%, repetition time of 2400 to 2500 milliseconds, echo time of 2 to 2.9 milliseconds, and parallel imaging of 1.5 × 2.2. The total image acquisition time varied between 5 min and 38 seconds to 7 min and 12 seconds.[31]

Image Reconstruction

The ABCD study team created structural MRI data from T1-weighted and T2-weighted images; those that had gradient non-linearity distortion were subsequently corrected to maximize the integrity of data across imaging sites. Likewise, tissue segmentation and sparse spatial segmentation were considered to correct intensity nonuniformity. 1-mm isotropic voxels were then used to resample images into fixed alignment within the brain atlas. Using the FreeSurfer software, version 5.3.0 (Harvard University, Cambridge, MA, USA), the ABCD team reconstructed the cerebral cortex and performed volumetric segmentation, with skull and non-brain material removed from images afterwards. The ABCD team then used mesh creation to perform White and gray matter segmentation. Using the procedures as described by others,[33,34] the ABCD team corrected topological defects. The images were then all optimized and registered non-linearly to a spherical surface-based atlas, and the ABCD team divided cortical regions into regions of interest (ROIs) based on a surface-based atlas classification.[35-37] This ROI data is available within ABCD data releases. Similarly, our study utilized pre-processed MRI data likewise available in files released by ABCD, with superior temporal cortical surface area data being the only sMRI data used. This was a continuous variable as measured in mm^3, with a higher value representing a larger ROI surface area.[31]

Imaging Quality Control

In order to maximize similarity and ensure comparability across scanning processes at different sites, a detailed harmonization process was used; thus, comprehensive quality control and harmonization protocols were very significant to the integrity and comparativeness of ABCD data.[31] Brain images of exceptionally poor quality or with extreme artifacts or irregularities were excluded from analysis following each image's manual evaluation.[31] Cortical surface reconstruction images were evaluated on the basis of motion, intensity inhomogeneity, White matter underestimation, magnetic susceptibility artifacts, and susceptibility artifacts.[31]

Results

Descriptive Data

Table 1 provides a summary of the descriptive data as provided by ABCD. In addition to cortical surface area values, Table 1 shows specific demographic data including household income, marital status of the children participants' parents, and the ages and sexes of the children. This sample of 6039 children was predominantly composed of White children (n = 5825, n% = 96.5%), with Asian children representing a significantly smaller portion of the sample (n = 214, n% = 3.5%). In both samples of White and Asian children, there were slightly more male than female participants. Specifically, 52.8% of the total sample was male and 47.8% of the sample was female.

Differences in demographic characteristics among Asian and White children can also be extrapolated from Table 1. Foremost, of the sampled children, there is a greater percentage of Asian children in households with married parents (88.3%) than White children in households with married parents (82.8%). Although most of both Asian and White children within this sample have household incomes over \$150,000, there is a greater proportion of Asian children with household incomes over \$150,000 in comparison to White children. On average, White children also had greater cortical surface area than Asian children (190,136.22 mm^2 vs 188,467.64 mm^2).

Fit of Model 1 and Model 2

As our Table 2 shows, the fit of our models was better when the SES (income) by race interactions were included. This suggests that allowing SES effects to vary by race better explain the outcome being cortical surface area.

Summary of Model 1 and Model 2

While high household income was associated with larger cortical surface area (Model 1), this effect was weaker for Asian than non-Hispanic White children, as observed by an interaction between race and household income on cortical surface area (Model 2). This means the effect of household income on cortical surface area depends on race and is weaker for Asian than White children. These results are shown in Table 3 and Figures 1 and 2.

Discussion

The results of this study support our hypothesis that household income is associated with the cortical surface areas of both White and Asian children, with higher household incomes associated with greater cortical surface areas. However, the extent of these boosting effects differs in magnitude between White and Asian children; we specifically found that White children from high-income households experience greater gains in cortical surface area than Asian children from high-income households do. This indicates that White children can experience the boosting effects of income on cortical surface area to a greater extent than Asian children experience.

SES indicators have already been established by previous research to impact cortical surface area; the findings of this study further reaffirm this phenomenon. For example, it was found in a previous study that those from families with higher levels of parental occupation (titles falling into the category of "higher executives of large concerns, proprietors, and major professionals") were shown to have larger cortical surface areas than those from families with lower levels of parental occupation (titles falling into the category of unskilled laborers).[38] Likewise, one of our previous studies found that a higher level of parental education is positively associated with increased cortical surface areas and higher reading levels among children.[24] This occurrence is due to the distal effects that SES has on environments surrounding a child. SES greatly influences factors such as: stress, linguistics, family composition, cognitive stimulation, parenting practices, familial interactions, prenatal care, family deprivation, toxins, sleep, and nutrition.[39] These factors all directly impact brain development to a great extent. Furthermore, it was also

Table 1. Demographics and Cortical Surface Area Overall and by RACE/ETHNICITY

Level	All	Non-Hispanic White	Asian American
N	6039 (100%)	5825 (96.5%)	214 (3.5%)
Household Income*, No. (%)			
<50K	762 (12.6)	735 (12.6)	27 (12.6)
≥50K& < 100K	1830 (30.3)	1780 (30.6)	50 (23.4)
≥100K	3447 (57.1)	3310 (56.8)	137 (64.0)
Married family*, No. (%)			
No	1025 (17.0)	1000 (17.2)	25 (11.7)
Yes	5014 (83.0)	4825 (82.8)	189 (88.3)
Gender, No. (%)			
Female	2852 (47.2)	2747 (47.2)	105 (49.1)
Male	3187 (52.8)	3078 (52.8)	109 (50.9)
Age (month), Mean (SD)	119.13 (7.54)	119.12 (7.53)	119.58 (7.87)
Cortical Surface Area (mm3)*	190077.09 (17619.73)	190136.22 (17649.95)	188467.64 (16735.32)

*$P < 0.05$

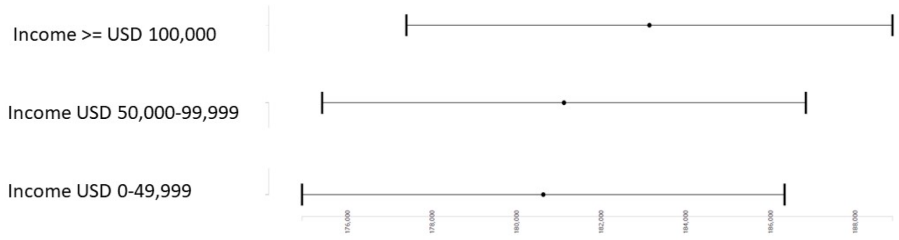

Figure 1. Association Between Household Income and Cortical Surface Area Overall.

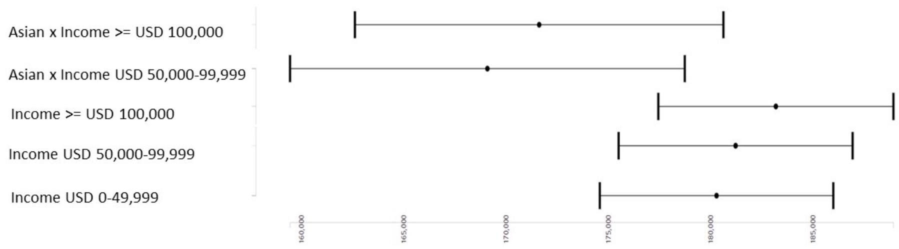

Figure 2. Association Between Household Income and Cortical Surface Area by Race.

indicated that White children experience the positive effects of increased parental education attainment to a greater extent than Black children do, despite both groups experiencing this association.[24]

Thus, the finding that household income is strongly associated with cortical surface area is somewhat to be expected and aligns with already known cases of higher SES positively influencing brain development. In terms of MDRs, it has already been established that Black children experience fewer benefits on health and brain development typically caused by higher SES than White children do. Long-standing structured racism, whether it be implicit labor market discrimination or social stratification, can indirectly prevent Blacks from experiencing the complete health benefits of SES. In this sense, health developments can also be a function race and ethnicity.

However, this current study which investigated the effects of SES on the brains of Asian and non-Hispanic White children has very important and relatively unexplored implications in terms of the MDRs phenomenon. Although the effects of MDRs have been relatively often documented among Black and Hispanic children, there have been noticeably less investigation into MDRs and the effect of SES on brain development among Asian children specifically. This is likely due to the problematic myth of Asians being a model minority, free from experiencing the effects of racism in comparison to other minorities. The findings of this study are therefore particularly significant because it further establishes that Asians are not exempt from experiencing the effects of MDRs and consequences on health as a result of racism, contrary to the notions posed by the model minority myth. Two aforementioned examples of MDRs among Asian Americans from our previous studies have also helped establish this occurrence. In comparison to White people, Asian Americans are less likely to experience preventative effects against tobacco usage typically associated with higher SES. Asian American children likewise experience less boosting effects on mathematical performance typically associated with higher levels of parental education.[23,40] Furthermore, another study

Table 2. Fit of Model 1 and Model 2

	Model 1 Main Effects	Model 2 M1 + Interaction
N	6039	6039
R-squared	0.24	0.24109
ΔR-squared	0.0037	0.00581
ΔR-squared (%)	0.37%	0.58%

Table 3. Summary Results of Model 1 and Model 2

	Model 1: Main Effects				Model 2: Interactions			
	Estimate	Std. Error	*P*	Sig	Estimate	Std. Error	*P*	Sig
Race/ethnicity (Asian)	-2344.47	1110.88	0.0349	*	5856.46	3151.24	0.0631	#
Married family	1084.53	631.19	0.0858	#	960.55	632.58	0.1290	
Sex (Male)	16889.21	390.51	< 0.001	***	16889.10	390.32	< 0.001	***
Age (Month)	-13.78	23.84	0.5631		-13.44	23.83	0.5727	
Household income [≥100K]	2508.54	735.20	< 0.001	***	2897.99	751.315	< 0.001	***
Household income [≥50K & < 100K]	489.05	749.65	0.5141		931.34	764.18	0.2230	
Household income [≥50K& < 100K] × Race/ethnicity (Asian)					-11194.39	3875.58	0.0039	**
Household income [≥100K] x Race/ethnicity (Asian)					-8665.50	3446.77	0.0120	*

#*P* < 0. 1, * *P* < 0.05, ** *P* < 0.01, *** *P* < 0.001.

found that being employed is more positively associated with higher self-rated health status rather than being unemployed among both Asian and White people; however, this boosting effect was stronger for White people than for Asians.[41] These trends suggest that there are potentially outward mechanisms acting on Asians that can lead to weaker positive returns of employment on health.[41]

These instances of MDRs can be attributed to various marginalization-inducing mechanisms that minorities are often subject to within America; primary examples include labor-market discrimination and impacts of general, everyday racism. Labor market discrimination is relatively prevalent among Asians: Asian people often experience ethnicity-based discrimination in employment settings, with participants from another study reporting experiencing discrimination when applying to jobs and obtaining equal pay, promotions, as well as housing.[42] Likewise, White evaluators are less likely to hire and promote Asian candidates into positions requiring social skills, ultimately acting as a mechanism behind limitations in Asian employment and upwards job mobility.[43] As a result of this labor discrimination, it is very possible that the quality of jobs for many Asian people is diminished in comparison to White people who do not experience these racial mechanisms to as large of an extent, if even at all. These additional difficulties in obtaining higher quality jobs and higher incomes thereby leads to additional stress on Asian parents which can indirectly affect children in households.

Everyday discrimination also hinders Asian health. Reported instances of general racism are associated with increased incidences of chronic cardiovascular and respiratory health conditions among Chinese, Vietnamese, and Filipino people.[44] Likewise, Asian participants were previously found to be significantly more likely than White people to avoid seeing a doctor or visiting other healthcare facilities in fear of experiencing discrimination, with 13% of Asian participants reporting having previously experienced discrimination when doing so.[42] Although these examples of racism do not impact Asian children directly, they very likely add to the stress of Asian adults and parents. These societal mechanisms therefore can have lingering effects into households with children, causing stressful environments and affecting their development indirectly.

Thus, these examples of employment discrimination and general consequences of everyday racism on well-being are byproducts of societal marginalization that Asians, like other minority groups, are subject to. This also demonstrates that brain development can at times be more so a function of the byproducts of racism than SES directly, since racism and discrimination can directly influence SES. This helps to explain the lapses in health, development, and well-being that Asians in the US experience, with factors such as these acting as additional stressors on Asians. These potentially explain the diminished returns of income on the cortical surface area of Asian children.

Ultimately, these additional marginalization and discrimination-based stressors elucidates to the idea that societal and racial mechanisms outside of individual, biological processes can lead to Asian children not benefitting fully from higher SES on cortical surface area. Given the reduced return of income for Asian children, a universal increase in income of all populations may generate some additional inequalities, simply because White people may show a larger uptake of the increase in income and turn it to outcomes. We should therefore be aware that our well-intended interventions always have the potential to increase the gaps across groups.

Implications

The findings of this study are especially important and may help us to uncover the byproducts of racism and discrimination in the lives of Asian families within the United States. Although we did not directly measure discrimination or racism, the observed MDRs indirectly suggest that Asians are also prone to experiencing consequences of ethnicity-based discrimination on health and brain development, contrary to some existing beliefs.

It has long-since been believed by some that Asian Americans, especially due to having seemingly more economic success in comparison to other minorities, are largely free of the repercussions of racial discrimination or other marginalizing systematic structures; however, this notion is problematic in that it glosses over the many effects of racism that Asians do indeed experience. As such, policies directed towards reducing racism and ensuing efforts to minimize inequalities can easily overlook and downplay the consequences of Asian racism. The results of this study therefore have important implications for future policy: it further emphasizes that equal access to resources or equal opportunities for economic success does not guarantee equity of outcomes. This is especially prevalent in terms of health among different ethnicities. Future policy needs to address structural inequalities to equalize the return of SES among diverse families rather than a single group benefitting disproportionately.

While the effects of discrimination and racism in American society that people across different minority groups experience can vary in magnitude and level of extremeness at times, it does not mean that racism a particular group experiences is insignificant or non-existent. However, there have been evidently fewer investigations into the impacts of racism and discrimination on Asian health in general in comparison to other minority groups. Thus, there is greatly a need for more research on anti-Asian racism and its impact on brain development of Asian children. Thus, the findings of this paper adds to the somewhat small yet growing body of literature demonstrating the role that race plays in diminished returns on health for Asian Americans.

Limitations

There are various limitations to this investigation that must be acknowledged. Foremost, this study was cross-sectional: because it is the nature of cross-sectional studies to compare different groups based solely on data from a singular moment, a definitive cause and effect relationship between income and cortical surface area cannot be certainly proven. Had the ABCD data been longitudinal with follow-up sMRIs of each participant produced and changes in household income noted over longer periods of time, a more definite causative relationship between household income and cortical surface area could perhaps be supported. However, this study is limited in that only correlation between household income and cortical surface area can be supported. Furthermore, there are limitations related to the sample size and sampling in this study. There was a sizable imbalance of representation within this study; Asian children represented a significantly smaller portion of the sample in comparison to White children. Namely, of the total 6039 children in the sample within the study, 5825 were White whereas only 214 were Asian; this small representation of Asian children limits the results' validity as well as representation of the larger populations of Asian children. Similarly, as aforementioned, the sample of children from the ABCD data is not nationally representative. While efforts were indeed made to increase the sample's generalizability to the United States, further studies are needed to replicate White children experiencing a larger boosting effect of income on brain morphometry in comparison to Asian children. Finally, in terms of brain scanning data, only a single sMRI indicator was used in this study. A more comprehensive understanding of the effects of income on brain composition and size could be achieved with multiple sMRI, dMRI, or fMRI measures across ROIs and brain structures rather than just the singular indicator.

Conclusion

In the United States, Asian American children are at a relative disadvantage in regards to experiencing the complete boosting effects of SES indicators such as income on cortical surface area that White children experience. This result aligns with previous findings that Hispanics and Blacks experience the benefits of SES indicators such as parental education and household income on health and development to a lesser extent than White people do. Through a lens of MDRs, we attribute these differences to non-biological, societal mechanisms: long-standing structures that inherently facilitate marginalization diminish the ability of minority groups to experience benefits of SES on health and development to the same magnitude that White children experience. Ultimately, these findings emphasize that policies that guarantee equity of outcomes among all groups of people in the United States with same level of investment in human capital and SES are needed. Likewise, further research is needed into buffers that can reduce the occurrence and consequences of the MDRs phenomenon. Such policies will be a step towards proportional returns of SES among all people. Only through policy and structural changes can we address the residual disparities and reduce racial and health inequalities in middle-class families.

Authors' Contributions

SA and AL contributed equally to this study.

Conflict of Interest Disclosures

The authors have no conflicts of interest to declare.

Ethical Approval

Not applicable.

Funding/Support

Research reported in this article was supported by the National Institutes of Neurodevelopment (U54CA229974, U54MD008149, U54MD008149, R25MD007610, U54MD007598, U54TR001627, and CA201415-02).

Acknowledgments

We thank the Adolescent Brain Cognitive Development (ABCD) participants and their families for their time and dedication to this project. Data used in the preparation of this article were obtained from the ABCD Study (https://abcdstudy.org/) and are held in the NIMH Data Archive. This is a multisite, longitudinal study designed to recruit more than 10 000 children aged 9–10 and follow them over 10 years into early adulthood. The ABCD study is supported by the National Institutes of Health (NIH) and additional federal partners under award numbers U01DA041022, U01DA041028, U01DA041048, U01DA041089, U01DA041106, U01DA041117, U01DA041120, U01DA041134, U01DA041148, U01DA041156, U01DA041174, U24DA041123 and U24DA041147. A full list of supporters is available at https://abcdstudy.org/federal-partners/. A listing of participating sites and a complete listing of the study investigators can be found at https://abcdstudy.org/principal-investigators/. ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in analysis or writing of this report. This manuscript reflects the views of the authors and may not reflect the opinions or views of the NIH or ABCD consortium investigators. The ABCD data repository grows and changes over time. The current paper used the Curated Annual Release 2.0, also defined in NDA Study 634 (doi:10.15154/1503209).

References

1. Jawabri KH, Sharma S. Physiology, cerebral cortex functions. In: StatPearls. Treasure Island, FL: StatPearls Publishing; 2019.
2. Stolp H, Neuhaus A, Sundramoorthi R, Molnár Z. The long and the short of it: gene and environment interactions during early cortical development and consequences for long-term neurological disease. Front Psychiatry. 2012;3:50. doi:10.3389/fpsyt.2012.00050.
3. Jirout J, LoCasale-Crouch J, Turnbull K, et al. How lifestyle factors affect cognitive and executive function and the ability to learn in children. Nutrients. 2019;11(8):1953. doi:10.3390/nu11081953.
4. Hackman DA, Farah MJ, Meaney MJ. Socioeconomic status and the brain: mechanistic insights from human and animal research. Nat Rev Neurosci. 2010;11(9):651-659. doi:10.1038/nrn2897.
5. Kelly PA, Viding E, Wallace GL, et al. Cortical thickness, surface area, and gyrification abnormalities in children exposed to maltreatment: neural markers of vulnerability? Biol Psychiatry. 2013;74(11):845-852. doi:10.1016/j.biopsych.2013.06.020.
6. Cafiero R, Brauer J, Anwander A, Friederici AD. The concurrence of cortical surface area expansion and white matter myelination in human brain development. Cereb Cortex. 2019;29(2):827-837. doi:10.1093/cercor/bhy277.
7. Hu H, Sun Y, Su S, et al. Cortical surface area reduction in identification of subjects at high risk for post-traumatic stress disorder: a pilot study. Aust N Z J Psychiatry. 2018;52(11):1084-1091. doi:10.1177/0004867417750757.
8. Hazlett HC, Poe MD, Gerig G, et al. Early brain overgrowth in autism associated with an increase in cortical surface area before age 2 years. Arch Gen Psychiatry. 2011;68(5):467-476. doi:10.1001/archgenpsychiatry.2011.39.
9. Amlien IK, Fjell AM, Tamnes CK, et al. Organizing principles of human cortical development--thickness and area from 4 to 30 years: insights from comparative primate neuroanatomy. Cereb Cortex. 2016;26(1):257-267. doi:10.1093/cercor/bhu214.
10. Shonkoff J, Levitt P, Boyce W, et al. InBrief: The Science of Early Childhood Development. Center on the Developing Child at Harvard University. 2009. Retrieved from: http://developingchildharvardedu/indexphp/resources/multimedia/videos/inbrief_series.
11. American Psychological Association (APA). Children, Youth,

Families and Socioeconomic Status. APA; 2018.
12. Brito NH, Noble KG. Socioeconomic status and structural brain development. Front Neurosci. 2014;8:276. doi:10.3389/fnins.2014.00276.
13. McLoyd VC. The impact of economic hardship on black families and children: psychological distress, parenting, and socioemotional development. Child Dev. 1990;61(2):311-346. doi:10.1111/j.1467-8624.1990.tb02781.x.
14. Assari S. Blacks' diminished return of education attainment on subjective health; mediating effect of income. Brain Sci. 2018;8(9):176. doi:10.3390/brainsci8090176.
15. Assari S. Parental education, household income, and cortical surface area among 9-10 years old children: minorities' diminished returns. Brain Sci. 2020;10(12):956. doi:10.3390/brainsci10120956.
16. Bureau U. US Census Bureau Releases New Educational Attainment Data. United States Census Bureau; 2020. https://www.census.gov/newsroom.
17. Budiman A, Ruiz NG. Key Facts About Asian Americans, A Diverse and Growing Population. Pew Research Center; 2021.
18. American Psychological Association (APA). Asian Americans: Model or Marginalized Minority? APA; 2021.
19. Kochhar R, Cilluffo A. Key Findings on the Rise in Income Inequality within America's Racial and Ethnic Groups. Washington, DC: Pew Research Center; 2018.
20. Kim M. Unfairly Disadvantaged? Asian Americans and Unemployment During and After the Great Recession (2007-10). Economic Policy Institute; 2012.
21. Amuedo-Dorantes C, Borra C, Wang C. Asian Discrimination in the Coronavirus Era: Implications for Business Formation and Survival. 2021. IZA Discussion Paper No. 14182. Available at: https://ssrn.com/abstract=3803726.
22. Mar D, Ong P. COVID-19's Employment Disruptions to Asian Americans. UCLA Center for Neighborhood Knowledge, UCLA Asian American Studies Center, Ong & Associates; 2020.
23. Assari S. Diminished returns of income against cigarette smoking among Chinese Americans. J Health Econ Dev. 2019;1(2):1-8.
24. Assari S, Boyce S, Bazargan M, et al. Parental educational attainment, the superior temporal cortical surface area, and reading ability among American children: a test of marginalization-related diminished returns. Children (Basel). 2021;8(5):412. doi:10.3390/children8050412.
25. Zucker RA, Gonzalez R, Feldstein Ewing SW, et al. Assessment of culture and environment in the adolescent brain and cognitive development study: rationale, description of measures, and early data. Dev Cogn Neurosci. 2018;32:107-120. doi:10.1016/j.dcn.2018.03.004.
26. Werneck AO, Agostinete RR, Cayres SU, et al. Association between cluster of lifestyle behaviors and HOMA-IR among adolescents: ABCD growth study. Medicina (Kaunas). 2018;54(6):96. doi:10.3390/medicina54060096.
27. Volkow ND, Koob GF, Croyle RT, et al. The conception of the ABCD study: from substance use to a broad NIH collaboration. Dev Cogn Neurosci. 2018;32:4-7. doi:10.1016/j.dcn.2017.10.002.
28. Morris AS, Squeglia LM, Jacobus J, Silk JS. Adolescent brain development: implications for understanding risk and resilience processes through neuroimaging research. J Res Adolesc. 2018;28(1):4-9. doi:10.1111/jora.12379.
29. Luciana M, Bjork JM, Nagel BJ, et al. Adolescent neurocognitive development and impacts of substance use: overview of the adolescent brain cognitive development (ABCD) baseline neurocognition battery. Dev Cogn Neurosci. 2018;32:67-79. doi:10.1016/j.dcn.2018.02.006.
30. Lisdahl KM, Sher KJ, Conway KP, et al. Adolescent brain cognitive development (ABCD) study: overview of substance use assessment methods. Dev Cogn Neurosci. 2018;32:80-96. doi:10.1016/j.dcn.2018.02.007.
31. Casey BJ, Cannonier T, Conley MI, et al. The adolescent brain cognitive development (ABCD) study: imaging acquisition across 21 sites. Dev Cogn Neurosci. 2018;32:43-54. doi:10.1016/j.dcn.2018.03.001.
32. Uban KA, Horton MK, Jacobus J, et al. Biospecimens and the ABCD study: Rationale, methods of collection, measurement and early data. Dev Cogn Neurosci. 2018;32:97-106. doi:10.1016/j.dcn.2018.03.005.
33. Jovicich J, Czanner S, Greve D, et al. Reliability in multi-site structural MRI studies: effects of gradient non-linearity correction on phantom and human data. Neuroimage. 2006;30(2):436-443. doi:10.1016/j.neuroimage.2005.09.046.
34. Cardinale F, Chinnici G, Bramerio M, et al. Validation of FreeSurfer-estimated brain cortical thickness: comparison with histologic measurements. Neuroinformatics. 2014;12(4):535-542. doi:10.1007/s12021-014-9229-2.
35. Ségonne F, Pacheco J, Fischl B. Geometrically accurate topology-correction of cortical surfaces using nonseparating loops. IEEE Trans Med Imaging. 2007;26(4):518-529. doi:10.1109/tmi.2006.887364.
36. Fischl B. FreeSurfer. Neuroimage. 2012;62(2):774-781. doi:10.1016/j.neuroimage.2012.01.021.
37. Fischl B, Liu A, Dale AM. Automated manifold surgery: constructing geometrically accurate and topologically correct models of the human cerebral cortex. IEEE Trans Med Imaging. 2001;20(1):70-80. doi:10.1109/42.906426.
38. Khundrakpam B, Choudhury S, Vainik U, et al. Distinct influence of parental occupation on cortical thickness and surface area in children and adolescents: relation to self-esteem. Hum Brain Mapp. 2020;41(18):5097-5113. doi:10.1002/hbm.25169.
39. Tomasi D, Volkow ND. Associations of family income with cognition and brain structure in USA children: prevention implications. Mol Psychiatry. 2021;26(11):6619-6629. doi:10.1038/s41380-021-01130-0.
40. Assari S, Boyce S, Bazargan M, Caldwell CH. Mathematical performance of American youth: diminished returns of educational attainment of Asian-American parents. Educ Sci (Basel). 2020;10(2):32.
41. Nicholson HL Jr, Ahmmad Z, Anderson A, Doan TT. Unequal returns of employment on self-rated health: Asian-White differences. J Racial Ethn Health Disparities. 2021. doi:10.1007/s40615-021-01050-3.
42. McMurtry CL, Findling MG, Casey LS, et al. Discrimination in the United States: experiences of Asian Americans. Health Serv Res. 2019;54 Suppl 2:1419-1430. doi:10.1111/1475-6773.13225.
43. Lai L, Babcock LC. Asian Americans and workplace discrimination: the interplay between sex of evaluators and the perception of social skills. J Organ Behav. 2013;34(3):310-326. doi:10.1002/job.1799.
44. Gee GC, Spencer MS, Chen J, Takeuchi D. A nationwide study of discrimination and chronic health conditions among Asian Americans. Am J Public Health. 2007;97(7):1275-1282. doi:10.2105/ajph.2006.091827.