



PROJECT
Viva

A STUDY OF HEALTH
FOR THE NEXT GENERATION

Celebrating Project Viva's *25th* Birthday

BORN IN 1998

THANK YOU FROM THE PRINCIPAL INVESTIGATORS

We are indebted to Matt Gillman and the other investigators who had the vision and tenacity to launch such an innovative study 25 years ago.

Project Viva has inspired generations of scientists, including ourselves, to conduct rigorous research to improve health during pregnancy and for women and children across their lifetimes. Literally hundreds of staff started their careers working on Project Viva, some of whom have remained with us for years and many others who have gone on to further training in medicine, nursing, nutrition, epidemiology, and public health. Most of all, we are grateful to the participants, who volunteered uncountable hours of their precious time (blood, urine, hair, and teeth as well!) to provide the important data without which none of this work would be possible.

Gratefully,



EMILY OKEN

Principal Investigator



MARIE-FRANCE HIVERT

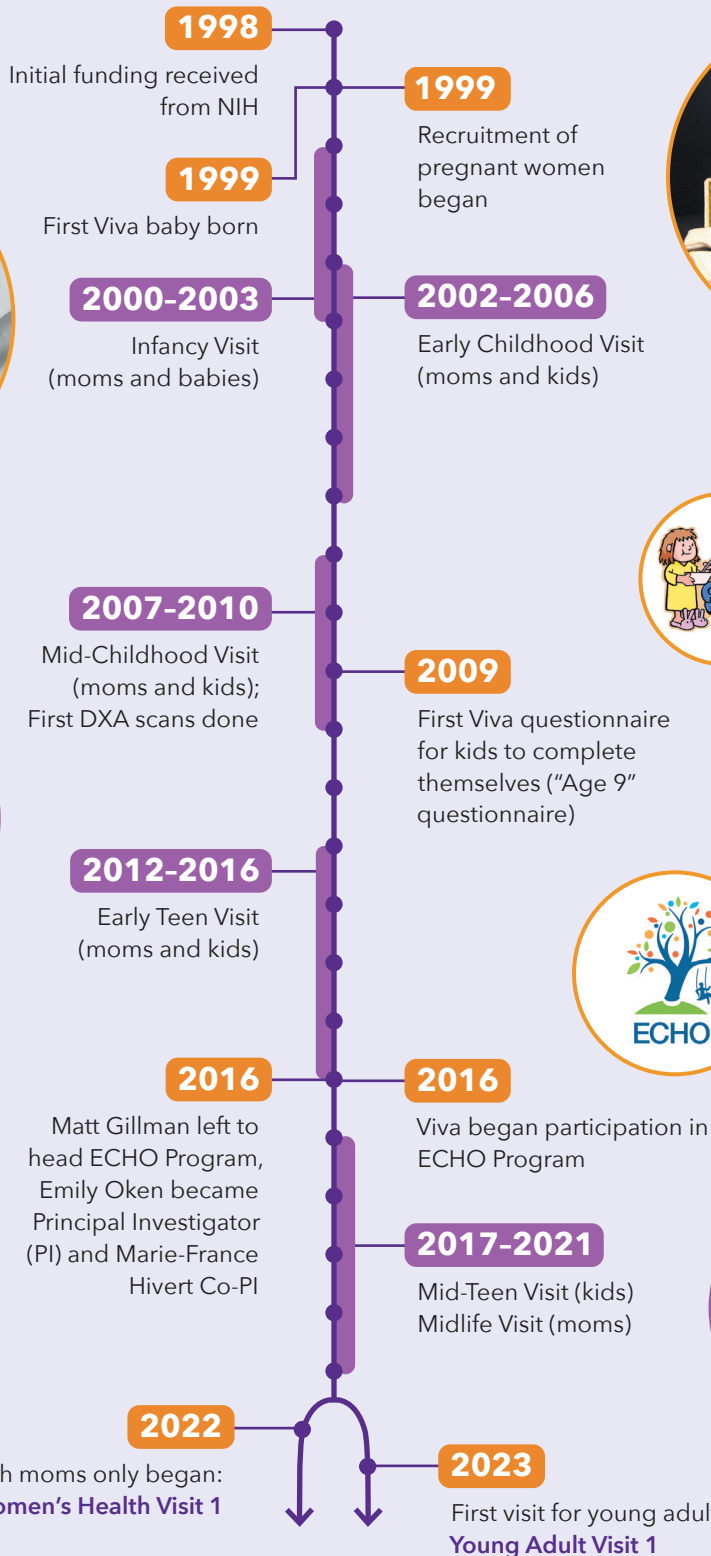
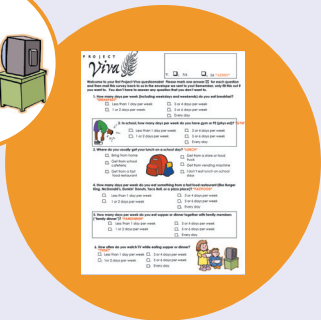
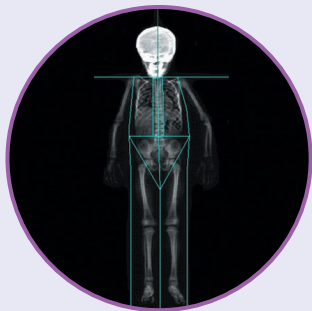
Co-Principal Investigator



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25 Years of Project Viva



REFLECTION FROM OUR FOUNDER

In the early 1990s, a seemingly peculiar theory arose – what happens before birth could have lasting consequences for a person’s health. I was skeptical that, say, foods a mother ate during pregnancy could lead to heart disease in her child many decades later.

Skepticism, though, can drive scientific inquiry. Thus with a team of collaborators, I applied to National Institutes of Health for funding to start a research study in which we would ask women during pregnancy to join and allow us to follow their children at least for several months after birth, if not longer.

By the time we secured support to start the study in 1998, the overall theory was maturing to the point that soon thereafter I felt comfortable co-writing an article entitled, “The fetal origin of adult disease: from sceptic to convert.” Now we were off and running in an exciting time to discover what some of these prenatal influences might be, and by doing that, inform the scientific community how to improve the health of the next generation.

Even when we started Project Viva, we knew that it could be more than our initial idea. Today, on its own and in collaboration with other studies, Viva has proven many times to be in the forefront of linking what happens during early development with health outcomes as children grow into young adults as well as how mother’s health evolves over time.

One of my great pleasures in directing Project Viva for its first almost 20 years was witnessing so many trainees and early stage investigators developing professionally with important Viva research as their medium. One of these trainees in the early days was Dr. Emily Oken. In 2016, when I moved to NIH to direct ECHO, a nationwide research program that includes Project Viva and many other similar cohort studies, Emily seamlessly transitioned to lead Viva, fostering a trusted team for expanding both science and a training ground for budding researchers.

When we started Project Viva, we surely wanted to be able to follow the kids longer than infancy. But 25 years! – that was a pipe dream. Yet with tremendous work by scores of staff and the dedication of thousands of participants, that’s exactly what has happened. Here’s to Project Viva’s next 25 years!



MATT GILLMAN
*Founding Principal
Investigator of
Project Viva*

Project Viva *at a Glance*

25+

Year longitudinal study

~115,000

Biospecimen samples stored

13
Countries are now home to Project Viva participants in addition to the US

2,128

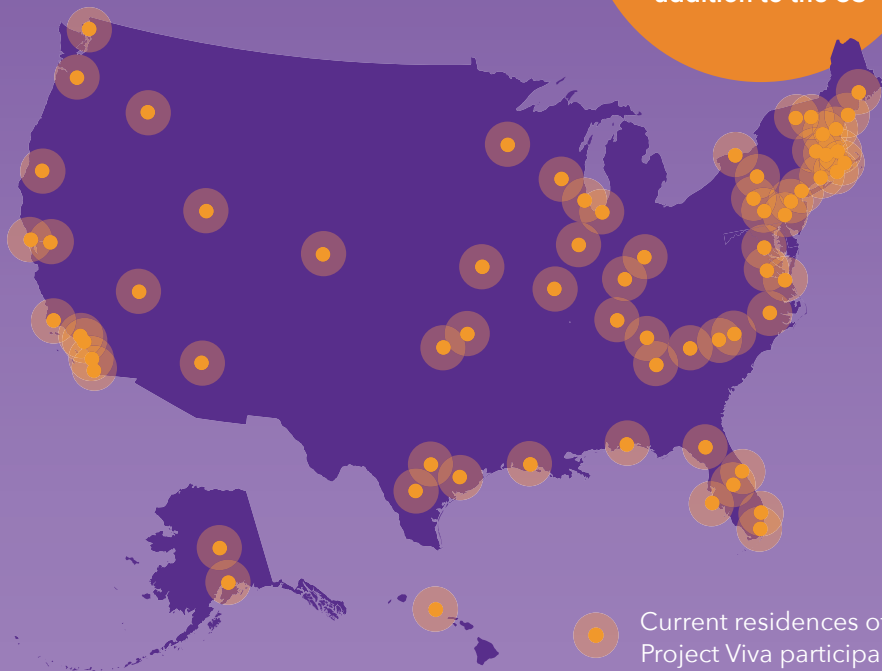
Enrolled births

~13,000

In-person visits

400+

Publications to-date



Current residences of Project Viva participants

FINDINGS FEATURED IN

The New York Times

U.S. News & World Report

CBS NEWS

FOX NEWS channel

CNN

The Boston Globe

Selected Findings

The following sections summarize just a few of the notable research findings from our 400+ (and counting...) publications over the past 25 years. We organized them around four types of exposures we have studied in depth (environment, neighborhoods, nutrition, and genetics); our four main health outcomes of interest (birth outcomes, cognition, asthma, and weight); and a separate section summarizing studies that examined health outcomes in moms.

ENVIRONMENT

Unhealthy environments are responsible for almost one quarter of the burden of disease worldwide, and pregnant women and children are especially sensitive to harms from pollutant exposures. We have measured many environmental chemicals using the blood, urine, hair, and tooth samples that Viva participants provided at study visits. We have also estimated exposures to pollutants in air and water based on home and school addresses.

We were among the first to demonstrate how pre-natal exposure to traffic pollutants can affect blood pressure, respiratory infections, and asthma risk in children. Other studies investigated how pollutants may reduce fetal growth and lead to obesity and impaired

neurodevelopment. Lead levels in Project Viva participants were generally low, but even such low exposures in pregnancy were associated with higher risk for preterm birth in boys, and behavioral problems in later childhood.

As is true in the population in general, every Viva mom and child we measured had at least some higher per-and polyfluoroalkyl substances (PFAS) “forever chemicals” in their blood. We have found that higher PFAS levels in early pregnancy were linked to a higher risk of pregnancy complications and impaired thyroid function. Higher PFAS levels in childhood were associated with more behavioral problems and later onset of puberty in girls and, in some cases, greater body fat.

NEIGHBORHOODS

Quality schools, parks and playgrounds, clean air, access to healthy food, health care, and safe housing help children grow up healthy. All these factors vary across the neighborhoods in which we live. We have conducted research in Project Viva examining relationships between neighborhood environments and various child health outcomes including obesity, cardiometabolic risk, and cognition.

Some of our work has used the “Child Opportunity Index”, a measure that combines data from 29 neighborhood-level indicators. About half of Project Viva children live in neighborhoods characterized as having “very high opportunity,” namely those with more access to the services children need to thrive. Viva kids from neighborhoods with more favorable opportunities in mid-childhood had lower blood levels of inflammation,

suggesting they are at lower risk for development of cardiovascular disease. We also found that residence in neighborhoods with more favorable opportunities predicted lower obesity risk from childhood to adolescence. Interestingly, these associations were stronger based on residence at birth compared to early childhood, indicating that pregnancy is an important window for exposure.

We have also found that living in a neighborhood with more green spaces (like parks and lawns) in early childhood was associated with higher nonverbal intelligence and higher visual memory in mid-childhood. These findings support the need for investment in public services and resources that can benefit the health of all children.

NUTRITION

Project Viva was originally designed to study the impact of a mother’s diet during pregnancy on her own and her child’s health, and we have continued our focus on how diet can influence health throughout life. We collected a lot of information from our mom participants about what they were eating while pregnant and about 6 months after their baby was born. Then we asked about how babies were fed after birth and once they first started having solid foods, as well as the child’s diet at different life stages as they got older. We have also measured other aspects of nutrition, such as household food security, sources of food, meal context, use of vitamins and supplements, and blood measures of nutrients such as vitamin D.

We have examined associations of the mother’s diet during pregnancy with aspects of her own health both during pregnancy and beyond. We found that diet during pregnancy was not a strong predictor of pregnancy complications like preeclampsia and gestational diabetes, whereas long-term diet before pregnancy is likely more important. However, healthy diet in pregnancy predicted lower likelihood of excess pregnancy weight gain, and healthy weight after delivery predicted return to pre-pregnancy weight.

In Viva kids, we have used these data to study how diet and nutrition impact all the health outcomes included in this report, and more! We have recently also started studying how early life factors shape children’s diets as they grow into teens and young adults. For example, infants fed breastmilk and who had later introduction of fruit juice had better diet quality later in childhood; picky eaters went on to have poorer diet quality.

Our diet assessments can take a long time to complete, but we have done, and plan to continue doing, so much important work with this information!



“Project Viva consistently pushes the envelope with cutting edge exposure and health outcome metrics. The cohort is a pioneer for setting the direction of environmental epidemiology.”

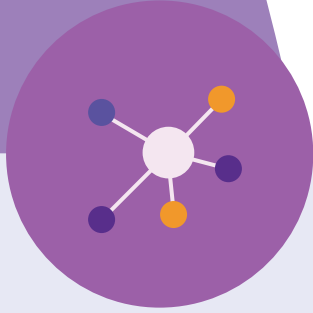
PETER JAMES, SCD
Environmental Epidemiologist and Viva Investigator

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My participation in Project Viva while I was pregnant with my first child has helped me to be a better mom in supporting my child to be on the right track. My Viva child graduated from school and is heading to college. I could say that Project Viva was part of his success!

VIVA MOM

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“Project Viva is special because it is a pre-birth cohort of well-phenotyped women and their children with two decades of follow-up — amazing data for exploring a wealth of questions on early origins of disease. Also, the Co-Investigator team is one-of-a-kind: brilliant, endlessly supportive, and kind.”

WEI PERNG, PHD MPH

*Nutritional Epidemiologist and
Project Viva Investigator*

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Something that I didn't think about when I first signed on was the message that it would send to my maturing son about the civic and moral value of adding to the body of scientific knowledge.

VIVA MOM

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GENETICS AND EPIGENETICS

About 99% of the human genetic code is the same across all individuals, but small variations make each of us unique. In rare cases, variations at one single place in the genome can lead to disease (for example, cystic fibrosis). For most health conditions, like diabetes or asthma, risks are affected by combinations of multiple common genetic variations. Studies with large numbers of participants are usually needed to study genetic risks for diseases. Thus, Project Viva has partnered with researchers from around the globe to analyze how genetics can affect pregnancy health such as risks for gestational diabetes, and child health measures such as birth weight, and obesity risk. This research has shown that many of the genetic variants that influence birth weight also affect blood pressure and risk of type 2 diabetes.

Health and disease can also be affected by signals on the DNA that tell genes to turn off and on; the study of which is called “epigenetics.” Unlike genes, which are fixed at conception, epigenetic signals can be modified by environmental factors. In work within Project Viva and in collaboration with other studies, we have identified epigenetic changes in babies' blood at birth that relate to prenatal exposures, such as smoking, gestational diabetes, and blood levels of mercury, lead, and PFAS chemicals. This type of research is especially important for informing prevention efforts, since pregnancy and early childhood are times when epigenetic signals are especially sensitive to these outside influences.

Impact on *Policy & Practice*

Medical, governmental, and other organizations have used our results to develop policies and guidelines for medical practitioners and the general public.



Our findings informed guidelines for healthy weight gain in pregnancy published by the **US National Academy of Medicine**.¹



The **Environmental Protection Agency** used Project Viva research in developing its Strategic Roadmap² on PFAS “forever chemicals,” setting policies to safeguard public health, protect the environment, and hold polluters accountable.



Project Viva’s research about prenatal fish intake and mercury exposure in relation to outcomes such as pregnancy health and child cognition influenced the **US Food and Drug Administration’s**³ guidance about fish intake in pregnancy and the **American Academy of Pediatrics**⁴ evidence review about fish intake in childhood.



For the first time in their 40-year history, in 2020 **The Dietary Guidelines for Americans**⁵ included advice on healthy diet for pregnancy and children under age 2 years. Project Viva’s research informed much of this guidance. Viva’s research was also cited in **The International Federation of Gynecology and Obstetrics** guidelines⁶ for healthy diet before and during pregnancy.



Our research on healthy lifestyle informed the work of the **White House Task force on Childhood Obesity** and Michelle Obama’s **Let’s Move!** campaign.⁷

¹ <https://nap.nationalacademies.org/resource/12584/Report-Brief---Weight-Gain-During-Pregnancy.pdf>

² <https://www.epa.gov/pfas/pfas-strategic-roadmap-epas-commitments-action-2021-2024#year-one-report>

³ <https://www.fda.gov/food/consumers/advice-about-eating-fish>

⁴ <https://pubmed.ncbi.nlm.nih.gov/31110165>

⁵ <https://www.dietaryguidelines.gov>

⁶ <https://pubmed.ncbi.nlm.nih.gov/26433230>

⁷ <https://letsmove.obamawhitehouse.archives.gov/white-house-task-force-childhood-obesity-report-president>





“During my fellowship, Project Viva gave me the opportunity to learn key academic skills such as posing a research question, analyzing data, writing papers, presenting findings at conferences, and writing successful grants. I am forever grateful for the strong foundation that Project Viva gave me, and for the continued support of long-time Project Viva collaborators, mentors, and friends.”

**MANDY BROWN BELFORT,
MD MPH**

*Neonatologist and
Project Viva Investigator*

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Thank you as always for all that you do. This cohort study is so important and I'm proud to have participated for the past 20+ years!

VIVA MOM

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BIRTH OUTCOMES

Both the length of pregnancy and fetal growth are important predictors of a baby's health during infancy and throughout life. In Viva, over 7% of babies were born preterm, which is more than 3 weeks before their due date, 5% had lower birth weight than expected, and 13% had higher birth weight than expected.

We have led research examining factors that can influence birth outcomes. In early work, we did not find that stress induced by the terrorist attacks of September 11, 2001 shortened Viva pregnancies. However, both shorter and longer than average menstrual cycle length in mothers before pregnancy was associated with higher risk for preterm birth. Environmental factors are very important (see page 4 for more of our work on environmental factors). Higher exposure to PFAS chemicals and higher pregnancy lead levels were associated with higher rates of preterm birth; and higher PFAS chemicals, maternal smoking, and higher air pollution levels all were associated with lower fetal growth.

In other studies, we have examined how these factors at birth predict later health of the child. Viva babies with higher birth weight went on to have higher weight, waist circumference, and body fat into adolescence. Thus, understanding factors that influence birth weight may be important for addressing the epidemic of childhood obesity (see page 11). Interestingly, preterm birth may also be a marker for future maternal health. For example, we found that Project Viva mothers with preterm deliveries had higher blood pressure and lower HDL (“good” cholesterol) 3 years later.

Our work to understand how birth outcomes relate to health has also led to important scientific advances outside Project Viva itself. Early on, we realized that there were no national standards that we could use to assign percentiles for weight at birth to the Viva kids. Using data from birth certificates across the US from 1999 and 2000, we developed a reference for size at birth. This reference has been used not only in Project Viva, but also in more than 500 other research studies, as well as in hospitals and clinics, to calculate weight percentiles for fetuses and newborns. In 2017, we updated this reference to keep it relevant for the next generation.

COGNITION

A baby’s brain grows at a staggering rate during pregnancy and early life. Early life environmental factors can impact brain development in ways that can influence cognition, behaviors, and risks for health conditions, like autism, throughout life.

For example, we found that higher maternal fish consumption in pregnancy was associated with better child vocabulary and visual motor abilities, although higher mercury levels, which can come from some types of fish, were associated with poorer cognition. Lutein and zeaxanthin are dietary antioxidant carotenoids found in many yellow and red vegetables. Higher intake of these carotenoids during pregnancy was associated with better offspring verbal intelligence and behavior regulation ability in mid-childhood. Additionally, greater dietary intake of these carotenoids in early childhood may help with later executive function. A better-quality diet overall during pregnancy was associated with better visual spatial skills in the offspring at early childhood and with better intelligence and executive function at mid-childhood. In a collaboration with the ECHO program (see page 12), we found that maternal prenatal tobacco smoking was strongly associated with an increase in autism-related symptoms and modestly associated with risk for a diagnosis of autism spectrum disorder.

More greenspace in the child’s neighborhood in early childhood was associated with better visual memory in mid-childhood, whereas greater exposure to traffic-related pollution may predict lower IQ and visual motor abilities. Both prenatal and early-life exposure to acetaminophen and ibuprofen were associated with poorer executive function and behavior in childhood. We also found that greater sugar consumption, especially from sugar-sweetened beverages, during both pregnancy and childhood, as well as maternal diet soda consumption in pregnancy, may adversely impact child cognition, while child fruit consumption may promote healthy brain development.

We hope that our findings in Viva will help set up children for bright futures with optimal brain power!

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We are hopeful this continued study results in positive change. Communication with Viva continues to be consistent, professional and always delightful – so, again, thank you. Oh, and by the way, the Viva onesies you gifted us are one of the very few things I saved from their babyhood.

VIVA MOM

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Project Viva has inspired me to be interested in research. I remember my mom teaching me about surveys and research through Project Viva by reading the findings and participating together.

VIVA KID

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“Viva started my public health career! It was my first job after getting my MPH from BU in 2000. It’s the oldest cohort of its kind in America – it’s especially unique because of the collection of bio-samples throughout time.”

CHELSEA JENTER, MPH
Project Viva Staff

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I love Project Viva and am proud to have been a part of it my whole life. I appreciate the effort that goes into keeping me a part of it (along with my mother) despite being across the world.

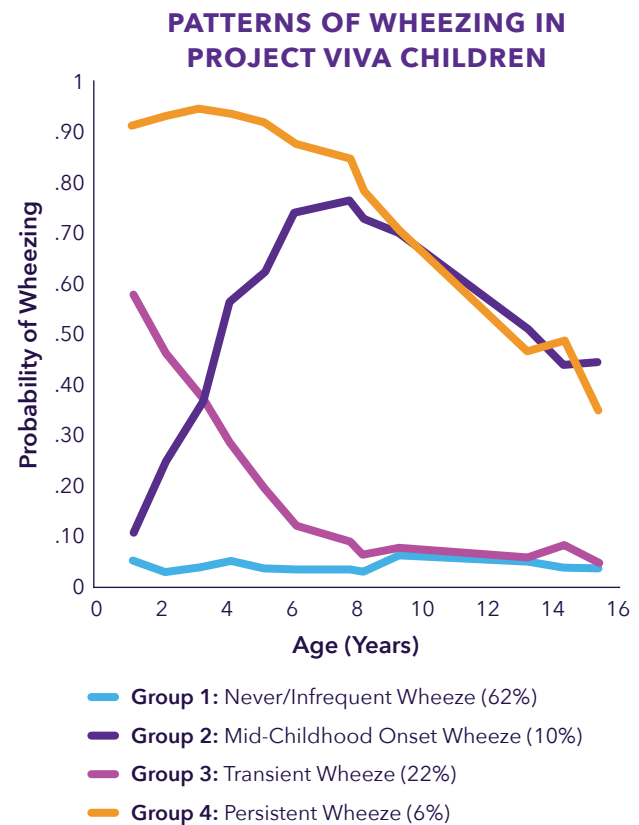
VIVA KID

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ASTHMA

Asthma is the most common chronic disease among children, affecting over 4 million (6%) US children. Asthma rates in New England are the highest of any region in the country. While asthma does travel in families, genetics is not the only cause – in fact, if a child has both parents with asthma, they have only a 50% chance of developing asthma themselves. Ninety percent of asthma begins before age 6 years, suggesting that experiences in early childhood – or even during pregnancy – are important for determining asthma risk.

In Viva, 29% of children were diagnosed with asthma at some point. Research in Project Viva has supported the theory that risk of asthma may be influenced by factors that affect inflammation. Exposures to air pollution, cigarette smoke, acetaminophen (Tylenol), sugary beverages, and stress can be “pro-inflammatory,” and we have found that these exposures are associated with higher asthma risks. On the other hand, factors like a healthy diet rich in omega-3 fatty acids and vitamin D are “anti-inflammatory,” and our research has shown that these factors may lower risks for asthma and wheezing. We have also been able to take advantage of Project Viva’s many years of following children to study how asthma symptoms can develop or resolve across childhood.



WEIGHT

The epidemic of childhood obesity remains a significant public health challenge worldwide. In the United States, rates of obesity among children of all age groups have tripled in the last 40 years to almost 20%.

At our in-person research visits, about 10% of Project Viva kids had obesity in both early childhood and mid-childhood, followed by 12% in early adolescence, and 13% in late adolescence. Project Viva research has identified early life risk factors for childhood obesity. For example, children whose mothers consumed a pro-inflammatory diet during pregnancy, with lower fruits and vegetables and higher saturated fats and starchy foods, gained more weight. This relationship was even greater among mothers who experienced excess stress. Also, mothers who gained excess weight during pregnancy had children with higher risk of obesity, higher body fat measured by our DXA scanner and body composition scales, and greater inflammatory markers in their blood. Smoking during pregnancy is another factor that, rather than being an appetite suppressant, predicted child obesity risk.

We also identified important risk factors in childhood. Intake of sugary beverages, including fruit juice, predicted higher overall fat and greater central “belly” fat in adolescence. Getting enough sleep, and a varied diet from infancy onwards, can each prevent later obesity.

These factors may act in combination. We found that the probability of being above healthy weight in adolescence varied from 9% for those with all favorable early life risk factors, to 64% among those with unfavorable levels of all. Differences in these early life exposures can even explain racial and ethnic inequities in obesity.

Since these predictors are likely to be amenable to behavior change, our findings will inform future intervention studies to prevent childhood obesity and, ultimately, its long-term cardiometabolic consequences such as diabetes and heart disease.

WOMEN'S HEALTH

Project Viva was originally designed to study the impact of exposures during pregnancy on children's health. We relied on mothers to bring Viva children to study visits and complete questionnaires about their children, home, and family. Viva moms also answered questionnaires about their own health and behaviors; completed measurements such as weight, blood pressure, and cognitive tests; and provided biological specimens; but we were initially interested in these factors for how they influenced their children's health. Within the past few years, we refocused our attention to how the wealth of data that Viva moms have provided could help us to better understand their own health.

We are now studying how different reproductive traits – such as experiencing difficulties conceiving and the frequency and regularity of menstrual cycles – are connected to current and ongoing health into midlife and beyond. To advance this research, we are collecting new types of data, such as menopause-related symptoms and conducting cognitive

function assessments, which will eventually allow us to track age-related cognitive decline. Although we are just getting started, we already have some interesting findings. For example, we have found that women with more frequent menstrual cycles during their reproductive years reach menopause earlier and experience more severe menopausal symptoms than women with less frequent cycles.

We have also found that women who experienced major psychological stressors – such as physical abuse, sexual abuse and financial instability – during childhood, adolescence or early adulthood experience more severe menopausal symptoms and poorer sleep quality decades later. We have also found that women who experienced difficulties getting pregnant or lost a pregnancy have higher blood pressure.

These findings reinforce the axiom that reproductive health is a vital sign for overall health among women.



ECHO

Environmental influences
on Child Health Outcomes

A program supported by the NIH

ECHO

The Environmental influences on Child Health Outcomes (ECHO) Program is a national effort to enhance the health of children through research that may help inform healthcare practices, programs, and policies. ECHO's Mission is: To enhance the health of children for generations to come.

The US National Institutes of Health selected Project Viva as one of 31 research teams to participate in ECHO from 2016 to 2023.

Overall, ECHO includes over **42,000 pregnant women** and **63,000 children** from 69 cohorts in 44 US States and territories.

Almost **800 Viva moms** and nearly **750 young adults** are enrolled in ECHO.

Using both historical data and ongoing data collection, ECHO researches 5 key health outcomes that have high public health impact:

- Pre-, peri-, and postnatal maternal and infant health
- Upper and lower airways health, such as asthma
- Obesity and related metabolic conditions
- Neurodevelopment, including behavior
- Positive health and well being



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Thank for all your hard work and I love participating in the program!!

VIVA KID

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Project Viva served as the foundation to launch my independent career with my first NIH grant as principal investigator and provided unique data and biospecimens to answer important questions.

ANDRES CARDENAS, PHD MPH

Project Viva Investigator and Environmental Epidemiologist

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When I was pregnant, we were told to avoid a lot of elements without any definitive proof of their effects. I was happy to help provide some real data.

VIVA MOM

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We have been very proud to be able to participate in Viva. We are happy to do what we can. My daughter has really enjoyed the little “treats” like body scan print outs and gift cards!

Participating has always been a positive experience.

Thank you.

VIVA MOM

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Viva is a special program because of its people. The Project Viva cohort and study team have positively impacted the lives of so many through their research and their generous support of investigators around the globe. I feel extremely fortunate to have had the chance to learn from and work with the Viva team!

EMMA PRESTON, PHD MPH

Research Scientist

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THANK YOU TO OUR FUNDERS & PARTNERS

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Infectious Diseases



National Heart, Lung,
and Blood Institute



Eunice Kennedy Shriver National Institute
of Child Health and Human Development

Thank you to all the Project Viva moms and
kids for a great first 25 years!



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