



# FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

## Ecology and Prevention of Growth Faltering in Nepal

### Webinar Transcript

#### Katie Heneveld

Good morning, afternoon, evening. Thank you all for joining this webinar to learn more about Ecology and Prevention of Linear Growth Faltering in Nepal. My name is Katie Heneveld, and I am an assistant researcher for the Feed the Future Innovation Lab for Nutrition, and I will be your MC for this webinar today. As attendees are joining the webinar, I will begin by going over some of some housekeeping items. I would like to direct all the attendees to a few functions on this Zoom webinar. At the bottom of your screen, you should see a chat icon and a Q&A icon. Use the chat feature to engage in relevant conversation with the other attendees. If you have a question for one of the panelists, please use the Q&A feature. Panelists will respond to questions in the Q&A box throughout the webinar as they are able, and we have allotted the final 20 minutes of this webinar for Q&As. If you're experiencing any technical difficulties, send a message in the chat box to "All Panelists", so our technical support staff can work with you to resolve them. This webinar is being recorded and will be made available on the Innovation Lab for Nutrition website and the USAID Advancing Nutrition website. There, you can also register for upcoming webinars and view recordings and slide decks of previous webinars. We will repeat these technical housekeeping items in the chat throughout the webinar as people may join in at later times. The moderator for today is Dr. Keith West. Dr. West is the George G. Graham Professor of Infant and Child Nutrition and Director of the Sight and Life Global Nutrition Research Institute in the Department of International Health at the Johns Hopkins Bloomberg School of Public Health in Baltimore, Maryland. He completed his dietetic internship at Walter Reed General Hospital and earned his Masters and Doctoral Degrees in public health at Johns Hopkins. Dr. West has worked in South and Southeast Asia, the Western Pacific and Sub-Saharan Africa, conducting collaborative research to prevent health consequences and reduce mortality due to micronutrient deficiencies in infants, children, and women.

He has served at the Johns Hopkins sub-award lead for Nutrition Innovation Lab activities, designing a nationally representative multi-year surveillance system to assess pathways from agriculture to nutrition in Nepal, known as Poshan studies. Professor West has authored over 260 scientific publications, is a recipient of the International Nutrition Prize Fellow and is the current Director at large for global nutrition in the American Society of Nutrition. Before handing it off to our moderator, I would like to introduce Dr. Patrick Webb, who is the Director of the Innovation Lab for Nutrition, and the Alexander McPharlan Professor of Nutrition at the Friedman School of Nutrition Science and Policy to provide a brief description of the Nutrition Innovation Lab. Dr. Webb, over to you.

#### Patrick Webb

Thank you Katie, Welcome to everyone, wherever you are. Welcome back for those who've attended previous seminars, and welcome aboard for those coming to us for the first time. This is the latest in a series of webinars showcasing some of the superstar researchers and amazing research done by them

around the world. This is part of a broad community of science to practice scholars who have worked over the last 10 years to try and untangle... tease out empirically challenging questions relating to: How does agriculture impact on diets and nutrition, specifically through what pathways? How does child growth relate to investments in agriculture? How could we see better design policies and multi-sectoral programs to support child health and well-being? And what kinds of biological mechanisms from environmental enteropathy and gut microbiome work to natural-borne toxins like aflatoxin? How do these impact on pregnancy outcomes and child physical and cognitive development? So, lots of challenging questions embedded in sets of studies in all of the countries that you can see here. To set today's webinar in context, you can see Nepal has had a lot of different studies, specifically it's not one of a dozen countries in which we've been working, but today we're going to focus explicitly on some of the things we've learned over 10 years in Nepal. It's not only relevant to Nepal, most of what has been looked at... many of the findings, many of the methodologies used are relevant globally and to policy and practice around the world, but we're going to hear some tip of the iceberg elements of the deep dive research that we did in Nepal.

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Of course, this has been a major collaborative activity in Nepal and in all the other countries as well as on global activity, and we certainly thank and recognize all of the partners with whom we've been working over these years. And then finally we certainly recognize the important engagement, as well as funding, of USAID and its partners. Both USAID and Washington and the USAID mission in Nepal, both of whom have been strong, strong supporters of this work and continue to be important collaborators in the research agenda. So with that, we'll move to Nepal and I will hand it over to our moderator for today, Dr. Keith West.

[Keith West](#)

Well thank you Patrick and let me express how pleased I am to be involved in this project and to be able to share, with everyone who's here today, some of the findings from the Poshan studies in Nepal. Let me offer my Namaste to colleagues in Nepal. It's a country that I first visited in 1976. I lived in Nepal in the late 1980s, had the pleasure of working with wonderful institutions in Nepal, setting up the Nepal Nutrition Intervention Project in Sarlai, working on vitamin A deficiency, prevention, and many other public health nutrition issues in Nepal over the years, one of which of course is also child growth and the prevention of stunting. And all that goes into that apparently simple measurement that has a very complex ideology. And one of a challenge to all of us to understand those ... excuse me... complex relationships that can bring them to a point where there can from time to time be a public health policy action taken to lessen this burden. So, it's a real pleasure to be here and to share with you findings on the ecology of stunting in Nepal, and some interesting tools and approaches toward how to move the pointer forward in further prevention in the years ahead. I would like to briefly introduce for now, and I will do more so a little bit later, our two speakers.

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I thought I had a slide there of Dr. Thorne-Lyman, Dr. Andrew Thorne-Lyman, who is an associate scientist in the program on human nutrition in the Department of International Health at Johns Hopkins. Andrew is a Nepal [wallah], he worked in Nepal in the 1990s and we'll say more about him a little bit later. Andrew will be giving his 40 year perspective on the trends of stunting in Nepal and preschool aged children, and offering some interpretations of those trends and their dynamics. And we have Dr. Swetha Manohar, who is a fellow at the School for Advanced International Studies at Johns Hopkins

University, a registered dietician I have met. She has a Masters and ... Public Health Masters of Science and Public Health and a Doctorate in Public Health from Johns Hopkins as well, and was project scientist for the studies that we are going to be describing today. We'll come back to Andrew and Swetha very shortly.

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I was looking for ... next slide please... a new map of the burden of stunting in the world, something that we haven't all seen, and just in time, the exemplars studies of stunting around the world appeared in the *American Journal of Clinical Nutrition* just in the past week or so, and so here is a fresh view of the burden of stunting around the world from *Vaivada et al*, that has just been published in a supplement. And it's a picture that we're quite familiar with, the peri-equatorial burden of stunting across Africa, and South Asia, Southeast Asia. We're focusing on South Asia today, and particularly in Nepal, where the province tends to be between 35 to 40 percent of stunting.

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A paper that our colleagues, *Harding and Aguayo and Webb* published not too long ago, just a couple of years ago, specifically focusing on the burden of stunting and wasting in South Asia, and showing that across most countries that have been looked at, listed there, the prevalence of wasting has been between 10 and 21 percent, and stunting has remained at 36 to 44 percent across these countries in recent years, with a lot of progress from the time of the turn of the Millennium until now. Interestingly, that paper by *Harding et al.*, shows that stunting among wasted children is around 34 to 47 percent, and among non-wasted children is 36 to 44 percent. And so, those relatively simple measurements alone start to tell us that there are different and complex etiologies that lead children to being stunted both when they are thin and wasted, but also when they are not. And that leads to the realization that there are many components to the causal pathway to stunting. And we'll explore those today.

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And we... that's series on the exemplars has given us a set of pathways that's got a refreshing tone to it that we are familiar with... contextual factors that either enable or suppress child growth that mediated through income and other resources that are available, that then guide the degree to which children are properly fed and households have adequate food security, modified by health care and other environmental factors that lead to dietary intake that is adequate or not, and what the burden of disease is and other factors that are going to affect how children grow and their prevalence of stunting in the population.

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However, what we're focusing on today is... I'm sorry go back to that slide... is to bring our attention to the process of growth faltering once we look at the prevalence of stunting, because stunting occurs because children are experiencing a deceleration or low linear growth velocity. So Dr. Thorne-Lyman will bring us up to date on the prevalence and the burden of stunting, what's happened over the years. And Dr. Manohar is going to offer some new perspectives and new tools for thinking about growth faltering as the process that leads to failed growth or stunting below two z-scores, below the median of height-for-age.

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So the aims of this webinar is to... is to briefly present the Poshan community studies, a series of mixed longitudinal nationally representative surveys that are linked longitudinally from 2013 to 2016, take a look at the stunting prevalence over the years, and present some interesting tools and approaches to assessing growth faltering.

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The Poshan study was conceptualized almost a decade ago. It has grown to be a project that covers the mountains, the hills, and the Terai, the lower plains of Nepal. Conceptually, it's been approached with the idea that there are agricultural... there's an agricultural basis to food security, dietary intake, quality of life, ability to access services that can affect the nutrition, and health of women and children. And the more we learn about those factors, the better we are able to inform policies and programs that lead to further assessments to look at the dynamics and the changes over time in these determinants of health and nutrition.

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A lot of what I'll say over the next few minutes has been published by a paper by *Ralph Klemm et al.*, on the pathways that were conceptualized and pursued in this project in Nepal.

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And briefly, this was a series of surveys that were carried out from 2013 to 2016, a nationally representative sample of village development committees, which were sub-districts at the time, to assess agricultural practices in very practical variables: animals grown the past year, harvest of crops during the rainy and dry season, for example, local markets that are the source of food for the local populations that were sampled, looking at different foods and their prices from year to year, looking at household food security using the household food security... household food insecurity assessment scale, constructing a wealth index, very practical measures. We did a food expenditure audit, dietary intake for seven-day food frequencies, and measured nutritional and health status by anthropometry as well as other factors. And the whole idea was to construct these potential pathways that can be studied and modified, that can improve diet and food security and nutrition growth of children. Today, we're going to focus on the longitudinal growth patterns and the determinants of stunting, but the Poshan surveys covered a wide range of factors.

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And so, this is a schematic at the time, there were 75 districts in Nepal. The country has been reorganized but we use ... we struck the organization of the country that was available for sampling at that time, and we listed the VDCs across the mountains, the hills, and the Terai starting with a random start and systematically sampled VDCs across those three agro-ecological zones. And we selected seven VDCs, which turns out to be also seven different districts across those zones. Within each VDC we randomly selected following ... systematically selected following a random start three of the nine administrative wards that occurred in each VDC.

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We could... we would like to have measured seasonality and be in all of those sites across all seasons. There are limited resources in public health, and so what we did was we picked a centroid VDC in the mountains, the hills, and the Terai: one VDC, three wards, and the way we selected them was that we went to the Central Bureau of Statistics of the Government of Nepal and chose the VDC in each of

those three zones that was closest to the central tendency for a whole range of variables that are available to measure communities in the country. So, we picked a centroid site across those three zones from the sample that we selected nationally. You can read more about that in *Klemm et al.*, but also other papers that I've listed there by *Broaddus-Shea et al.*

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Just a quick sideline on that. This is the wasting, and stunting, and weight-for-age, and height-for-age and weight-for-height of children in the mountains, hills, and the Terai in the overall samples that were chosen in those zones and the centroid site. You can see that the sentinel site that we picked was quite close in terms of nutritional status of the children, and that was true across a wide range of variables as well. So we did pretty well on picking the sites that we then followed season after season for a couple of years. We won't be talking about that today.

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So here is the new administrative division of the Federal Democratic Republic of Nepal just to acknowledge that it's been reorganized however.

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Our sampling was in line with the previous organization and the sites in gray and whatever that color is in the middle... green and dark green, are the mountains, and the hills, and the Terai sites that were sampled across the country for this series of studies. And so we chose the same 21 sites, same 63 wards at the same time of year - monsoon, mid-year each year - and targeted households that had preschool-aged children, and households that also has newlyweds, because they would likely have children, young children in the years that would follow.

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And so, if we look at the left side, 2013 was the first survey and we surveyed all households in those sites and identified those that were eligible. And then each year we went back to those same sites, same households, but we added new households that were identified with... that were eligible. And as we went from year to year and children aged beyond 72 months, we stopped following those. So we blocked the assessments to children under 72 months of age in subsequent years.

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We looked at community factors, so market infrastructure, community infrastructure, agricultural assets, and practices that were... that could be defined at a community level in each of these areas.

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And we looked at household factors that ... from the point of view of agricultural inputs and outputs... that can affect food security and influence expenditures on foods and other factors of the households that comprise the context in which people live at the household level

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And at the individual level, children and mothers were our target, looking at dietary quantity, and quality, and health status indicators, and nutritional status and across those levels, we looked at cross-cutting factors that are ... that relate to... that can be related to the issues of interest. This included... our colleagues at Tufts organized a district level assessment of programs that were feeding into each of the districts, so that we would have the full picture of what programs and policies are filtering in through the country into the district level, and what the uptake is and conditions are of the populations within those districts.

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And I won't go into this further... there are forms... and the reason I say this is because this data set... these data sets are available, and so we have examined factors at the VDC level, and local markets, local wards, and these levels that I just described.

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Relevant to this seminar today, there was a great deal of work that went into training and standardizing for anthropometry, height, weight, and arm circumference were the basics, and so we had 21 teams that had to be trained each year, 2013-14-15-16, following the same protocols and assessing inter/intra-observer error to get workers to be as similar as possible in their anthropometric measurements, and then fanning them out across the country to do the surveys with some quality control assessments this year in spot samples of these teams' work each year.

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Just a few pictures of the training that went on for each year for anthropometry

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And Dr. Manohar with her colleagues in Nepal carrying out the standardization training sessions.

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And here is a very quick summary of the kinds of data that are then in the Poshan community surveys, the 21 sites... VDCs across the country, except in 2015 when the country was hit by a major earthquake in the late April and through May of that year that made it impossible to carry out the surveys in the mountains and the hills. It was carried out... we did carry out the surveys in the Terai and the sentinel sites that I mentioned earlier in 2015. And so we had around 5000 eligible households most of the years, except for 2015, interviews completed with about 5,000 women of reproductive age and around 4,500 to 5,000 or so children under 5 years of age, which we will focus on the Terai samples today.

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And these data are... the survey data are available at the Johns Hopkins Data Services Dataverse at this site for those who may be interested in pursuing question on their own

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I'd like to quickly acknowledge the many ... early in this webinar ...the many institutions that have been involved. Our thanks to USAID, both in Washington D.C. and Katmandu, an agency that has been working on nutrition in Nepal for half-a-century. So we're very appreciative of the support, our colleagues at Tufts University that have managed this massive project and collaborating with across not only Hopkins, but many other institutions, the National Planning Commission, Child Health Division of Nepal, and the Ministry of Health and Population...could not be done without all of these institutions, and some that are listed along the bottom: New Era which carried out the field work, and NTAG which assisted in the field work and the organization in many aspects of the work that is being presented today.

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And of course it takes individuals to do these studies and this is just a quick list of some of the key individuals that have been so important in carrying out the work over the years in this project.

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And so Dr. Andrew Thorne-Lyman is an associate scientist in the program in our nutrition at Hopkins. He is a nutritional epidemiologist, has his Masters and Doctorate from Hopkins and Harvard. He is interested in food systems and diets and how they relate in affecting nutrition and health of children and women, with particular interests and indicators of how they could be mounted and deployed for evaluating programs. He has worked with World Fish, Columbia University, the World Food Program, and Hellen Keller International. We're very pleased he's at Johns Hopkins. So he'll be talking to us about child growth in Nepal giving a 40-year perspective and our second speaker.

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Will be Dr. Swetha Manohar, who is a fellow at the School for Advanced International Studies who will be covering some very interesting issues related to both velocity as an approach to measure growth velocity... as an approach to try to prevent childhood stunting. Swetha has her Masters and Doctoral degrees from Hopkins. She is a clinical dietitian, a registered dietician with the Academy of Nutrition Dietetics. She was the project scientist... the Hopkins project scientist for this project, living in Nepal for several years, and with broad research interests in child growth disparities in food insecurity and evaluating programs that can affect the nutritional status of women and children within the context that all this occurs. So without further ado, I would like to turn the microphone over to Andrew and proceed with our webinar. Andrew.

[Andrew Thorne-Lyman](#)

Thank you so much and a special Namaste to all of my colleagues throughout the world. I think one of the silver linings and there's a very few silver linings to this epidemic, is just that the ability to have webinars like this and to see so many familiar faces from all over the world. I'd like to just begin by again acknowledging the great set of collaborators that we have, you know, in Nepal, in Boston, you know, and a special thanks to USAID for making this possible, this research. So, today I'm going to be talking

... taking sort of a longer term perspective to examining trends in child growth in Nepal.

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I think there's been... there's been a number of papers published over the past five years, you know, one of the rich outstanding things about Nepal is that there's.. that there is a lot of data and there's a lot of interest in understanding of the success story of, you know, that has been seen with reducing child stunting and improving that aspect of child malnutrition over time. So there's been a lot of research that's gone on. I think one of the novel things that we are hoping to present today is taking a longer term view of how things have evolved over time, and so that's what I'm hoping to cover today. But then also hopefully to give some food for thought around the strengths and the limitations of the present approach, you know, that's being used in a lot of papers to look at the risk factors for child malnutrition, and specifically child nutrition.

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So all of the work that I'm presenting today is from published papers, and I know we're all busy, and we all are in our own silos, and sometimes it's difficult to know about all the papers that are out there. We've put all of these papers, they're all publicly available online at the Nutrition Innovation Lab website and there are links to those. The majority of the work that I'm presenting today comes from a paper that was recently published in *Food and Nutrition Bulletin*, the one on the left led by our colleague *Angela K.C.*, similar to the title of my talk today. There's... there's a few other papers that I'm presenting work on: one was led by *Sudeep Shrestha*, where we examined the pre-earthquake, as you know most there was an earthquake that happened in Nepal in 2015. So we examined sort of the pre-earthquake national patterns of child stunting and wasting. Then, there was another paper that I did that sort of zoomed in on the hardest hit earthquake hardest... the areas that were hardest hit by the earthquake, and examined what happened with child malnutrition, food insecurity, and other indicators in those areas. And then also we had done a risk factor analysis led by *Jamie Dorsey* published in 2018 that looked at a wide set of factors associated with child stunting.

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So Dr. West already presented the general methods of the Poshan studies. Today though I'm going to be presenting data both from Poshan surveys, the national surveys from 2014-15 and 2016, but then also presenting that alongside a number of other national surveys. Nepal is somewhat unusual and there actually is more than 40 years of data ... national data on child nutrition to examine, although a lot of efforts... prior efforts had not made use of the 1975 Nepal Nutrition Status Survey. We've included that in our analysis to try to give an



understanding of what happened, what might have been the situation before this remarkable decline that has been highlighted in a lot of the studies. And then, we're also making use of the five-year ... the DHS surveys that were conducted every five years starting in 1996. We'll use the WHO Growth Standards for most of these surveys, with the exception of the 1975 survey, where we didn't have the original data. So all of these were original analyses...primary analyses that we conducted, except for that one where we just sort of have to use what's available. And in that survey, because we didn't have the original data, we're relying on a different threshold of less than 90 percent of the median to define stunting. For the rest of the papers in the analyses, we're using a cutoff of less than 2 z-scores. And another limitation is just that for the 1996 DHS survey, because data was not available for all under-fives, we're only presenting that for the under threes. And all of the confidence intervals that I'm presenting reflect the complex survey design.

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So we've divided the trends in malnutrition in the country into three sort of phases, and the first phase lasted 25 years, from 1975 to 2001. This is a phase where there was sort of ... a lot of stunting. About half of the children in this period, you know, at both the 1975 survey and the 2001 DHS were stunted. There's some suggestion that the situation may have worsened over this period, and just a long absence of data in between those two data points. So we don't really know exactly what happened in between those points, except we do have some clue.

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The 1996 DHS... this is analysis of ... a sensitivity analysis that we did where we looked at under-threes only, and just saw that there actually probably was a little bit of a rise before the DHS.

Next thank you

So in Phase II, this is a story that has received a tremendous amount of attention, you know, through the exemplars work... through the drivers of change work that has been done, you know. It's one of the most rapid declines in stunting that's been observed historically in any country. Some of the prior analyses that have looked at this have attributed this improvement to greater assets, greater availability of health services, growth in education, parental education, but especially maternal education, and also growing access to toilets and reduced open defecation. Now we added our data point of 2013 there, which really suggests that the decline continued past the 2011 DHS, and actually probably continued through to 2013, making an annual rate of reduction of 3.8 percent from 2001 to 2013.

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Our 2014 survey however suggested that stunting probably leveled off around 2014 prior to the earthquake, and also suggested that wasting over this period ... we didn't observe know sort of clear trend patterns, but that wasting had quite a high prevalence, exceeding 15 per cent nationally in both our 2013 and 2014 surveys

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Now, we know in 2015 Nepal was affected by a devastating earthquake...

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... That left 9000 dead, tremendous amount of injury, a lot of displacement. The earthquake also occurred at a time when households were about to plant their rice in the fields, which is the dominant crop in Nepal, leaving a lot of open questions about what would happen to the situation. You know... we know that there was a lot of deaths, a lot of damage to houses, but what the impact was on nutrition had not been well studied prior to our analysis.

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And so, by virtue of having this infrastructure in place and these prior surveys that had been done leading up to the earthquake, we had a number of sites where we could actually look at what happened in the hardest hit areas. And you can see there the epicenter of the earthquake was in the north, northeast of the country that's on the left, and on the right you can see the surveyed sites where we had data available. And so, what we did was we wanted to look... we had a 2016 survey ... we didn't collect data in 2015 because of the earthquake, but we were able to follow up a year after the earthquake to see what had happened, both nationally and in these hardest hit areas.

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And so, here's sort of an overview of the study design. And so we both cross-sectional... the ability to analyze cross-sectionally what happened before a year before the earthquake and a year after the earthquake to households women and children. But then also by virtue of the design, we have a longitudinal cohort as well of the same households, women and children, before and after the earthquake in these hardest hit areas

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And you can see here some of the findings, you know, which echoed, you know, the assessments that had occurred immediately after the earthquake, that a lot of households experienced damage, structural damage to their houses, job loss, injury, etc.

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Now kind of paradoxically, these were unexpected findings. We found that the wasting ... the prevalence of wasting, stunting, and food insecurity decreased in 2016 relative to 2014, which was somewhat unexpected and somewhat hard to explain.

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At the same time, this slide presents what happened with the agricultural situation in terms of crops, and so the bars indicate the average production of each crop that the household reported in kilograms. And the lines represent the proportion of households that grew each

crop before and after the earthquake. And you can see that there was a decline in rice, but it wasn't very much. In most crops actually there was a decline. But it was ... it was somewhat comparable so it really did help to answer that question of whether or not households were able to get the crops out in the field and plant it, and the harvest was not did not do as poorly as some had anticipated.

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So the same findings, we saw some similar findings of the overall national situation with respect to the prevalence of malnutrition as we saw in those hardest hit areas. And so we ... in this Phase III sort of analysis... the third phase of where malnutrition is in Nepal, we saw that the 2015 earthquake did not apparently seem to have a strong impact on stunting. If anything, things may have gotten a little bit better after the earthquake, but what we saw was that there does appear to be a leveling out, as you can see there, of the prevalence of stunting, at about 35 percent, and this was seen in 2013, 2014, in the 2016 DHS as well, and in our 2016 Poshan survey. So remarkable stability there.

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And this gives just sort of the entire time series overview, so you can see where the country has come from, and where we are now, at least prior to the COVID-19 situation. Really much more frequent surveys from 2013 suggesting that there is a leveling off ... suggesting that perhaps we need to make some changes or some changes were needed to be able to have continued reduction in the prevalence of stunting.

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And prior analyses have highlighted, you know, this five year interval from 2011 to 2016. If there was a reduction that happened there of about 5 percent or a little bit less or about 1 percent per year, but when you fill in the blanks, they're in between with these other national Poshan surveys, you can see that it is quite stable.

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So there have been, as I said at the beginning of the presentation, there have been a number of analyses of the drivers or of the risk factors associated with child stunting in the country. We had done in 2013 an analysis of the factors in the Poshan study that were associated with child stunting cross-sectionally, and many of the same factors that you see highlighted in the other risk factor analysis, which you can see here in bold at the child level, maternal level, and household level, are the same as other analyses have suggested, but by virtue of having sort of a more comprehensive module ... set of modules to look at other factors, we were able also to look at things like for example: whether rubbish on the compound was associated with greater stunting, it was things like expenditures, and expenditure on agricultural inputs, things like at the community level like a less developed infrastructure were also associated with child stunting.

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And so I think, as I said at the beginning, the cycle of this presentation was really to discuss this approach to looking at risk factors. And there's two main points I'd like to make here. And the first is just when you read these types of analyses, it's important to keep in mind that you're looking at the risk factors for prevalent cases of stunting, and given that stunting is a process that happens over time, it's a cumulative process, it's important to just reflect on the fact that you know you see there the circle... those are the children that that are being stunted or being classified as stunted, and it's probably the younger kids who are in such analyses who are not stunted. And so essentially what we're doing in these types of analyses is you know looking cross-sectionally at a set of risk factors... we're sort of making an assumption if we want to draw some sort of ideological connection of the causes of some of these things, if we want to think about the causes, we're assuming that the causes that are currently associated with stunting are the same causes that were associated before. And so there's essentially a misclassification of those factors that's going on. So that can be a limitation, and another limitation of these types of analyses is just the survey content. So when we relate, you know, factors to stunting or to any outcome, we're limited by what's in those survey modules. And so, you know, when people are making conclusions about the drivers that contributed to the change of stunting or other indicators, you know, they're limited to what's in those survey modules. It's a good job... a lot of information into, you know, into their surveys, but there's not a lot of information about agriculture, about other risk factors there, and so that's another limitation of these types of analyses.

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And so with these limitations in mind, I want to hand over the microphone to... I guess it goes back to you Keith and then to... Dr. Manohar who's going to present, I think, you know a potential approach to overcome some of the challenges associated with the first limitation that I described.

Swetha Manohar

Everyone, good morning, good afternoon or good evening depending on where you are. It's a pleasure to be here today with all of you and I'll be walking you through the last presentation of this session, and it will be focused on assessing low growth velocity and its antecedent risk factors to prevent childhood stunting.

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So we are all aware obviously by these presentations that child growth is an important marker of well-being and there is a high degree of investment in improving the linear growth of children. Stunting is one of the most commonly used metrics and it is defined as being too short for one's age against ... compared to a global standard or reference, and in the global nutrition world typically, what is used as the standard is the WHO Child Growth Standards. But this is a state that reflects growth that has already failed and faltered as measured by this attained indicator.

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So, what is linear growth faltering then as opposed to stunting? Linear growth faltering is an abnormally low rate of growth and does not necessarily imply that a child is stunted, although they could be, and growth faltering reflects a more dynamic process of sub-optimal growth. It reflects a process where children are on the pathway to the failed stunted state, and it's best measured with velocity metrics, also known as growth rates.

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So the motivation for this work was that we felt there existed a need to measure the process of faltering growth, and to understand growth faltering prior to a child becoming stunted or experiencing failed growth to potentially prevent stunted growth. It was... we also were motivated to identify children faltering in their linear growth, as reflected by a low growth velocity, irrespective of their attained height status, and to reveal patterns of growth and associated risk factors that could potentially be modified, using annual growth velocity metrics, which take into account that growth can be impacted by seasonality. Finally we also ... to assess, analyze annualized linear growth velocity one requires a growth velocity reference that covers the entire preschool age period, which currently does not exist. And so this was the motivation for our work. In terms of specific aims, Aim 1 really focused on estimating the patterns of growth faltering in children to 0 to 71 months of age in Nepal. Specifically, we derived a pragmatic annual linear growth velocity reference by age and sex to cover the entire preschool age range, and then to demonstrate its utility in assessing growth faltering at a population level.

Keith West

Sorry Swetha, I think you need to advance this slide.

Swetha Manohar

I'm sorry. And secondly, we had to identify individual risk factors that were associated at the household, individual, and community level with growth faltering, as linear and growth faltering defined as a linear growth velocity z-score of under minus 2.

Next slide

Both these study aims were embedded in the Poshan community studies that were described by Keith already.

Next slide

Andrew's already walked you through what are compelling reasons to study child growth in Nepal, given the burden of undernutrition. But this particular work was focused in the Terai,

which is the southern plains of the country, and it houses approximately 50 percent of the country's population, and is the breadbasket of the country, primarily agrarian in terms of work, and is vulnerable to natural disasters, which include and climatic shocks ... which include floods, tornadoes, and earthquakes. And the communities residing in this area of the terrain do live life by seasons as many agrarian communities do.

Next slide

So very briefly, I'll touch upon the study designs for the specific aims of this work. As I mentioned it was ... we embedded this work in the Terai sample, you can see that on the right I guess of your screen, and it included seven 7 VDCs and 21 wards in total, with all households with a child under five in the study ... consenting to the study enrolled. And for this particular analysis, we restricted the study sample to children who were under 16 months of age at their first visit, and also children who had at least 2 consecutive length-for-height measurements, between 2013 and 2016. So in total this allowed us a sample size of 4,497 children.

Next slide

So for specific Aim 1, just to revisit, this was focused on the derivation of an annual linear velocity reference, and also we sought to demonstrate its utility in estimating population level growth faltering.

Next slide

So as I mentioned before, to evaluate annualized growth velocity of children, we needed an annualized velocity reference with which to compare our population. So we conducted a detailed search of existing references or standards and we weren't able to find globally representative annualized linear growth velocity which ... or standards that provided an annualized increment by each month of age against which to compare our population. So as such, we combined the widely used references... the WHO wrote standards from ages 0 to 12 and then the well-known Tanner reference velocity reference from British children from 13 to 59 months. And the justification for combining the WHO standards and the Tanner references is that multiple studies have shown that among children who do not experience socioeconomic and health access limitations regardless of their geographic location, that there's a little there's little variation in linear growth and their linear growth distributions are comparable.

Next slide

And this seems to be to hold true in our predicted linear growth velocity curves that we computed. So the combined and derived reference of annualized estimates for this particular growth velocity curve shown here was produced using restricted cubic spline models given the nonlinear relationship between height velocity and age. And these models produced smooth continuous fitted sex specific median curves that best fit the data. So the dots and the Xs you

see on your screen are the modeled predicted values and the derived median reference curve for annualized velocity for boys in turquoise and girls in purple are the curves that you're looking at is what you see on this graph. And as you would expect, you can see a monotonic decline in high increments as shown in age for both boys and girls, and essentially rate... this is showing that rate of growth slows as children age.

Next slide

So to measure linear growth velocity, a rate of growth needs to be estimated, and this was done using the formula that you see in the orange box. Height velocity expressed as centimeters per year was calculated as the difference between two height measurements divided by the time in between, which was taken a year ... these measurements were taken a year apart. And finally to annualize this rate, it was multiplied in by 365 days. In total for this aim, I calculated 8,382 growth intervals for 4,447 children

Next slide

So when we plot these annualized height velocities of Nepali children against the WHO Tanner reference for boys and girls, we get these plots. So each of the gray dots reflect individual boys or girl velocities, that is their annualized growth interval, and the collection of dots is the distribution of these growth velocities. The solid turquoise and purple lines reflect the median reference curve, and the top and bottom lines are the two positive 2 and minus 2 z-score reference curves. So overall, what you're looking at is that majority of the study children who are at a velocity below the reference median regardless of their age. If you bring your line of vision to that median solid line, you'll notice the distribution of gray dots below it. To estimate... if you can just click ... to estimate population level growth faltering, we proposed a metric by which we can evaluate growth faltering using a linear growth velocity z-score, the z-score formula for which is presented here. I feel like some of it is slightly cut off but...yes.

Next slide

So when we look at the linear growth velocity expressed as z scores, a departure from... can you click Chris, thank you... a departure from the median reference was marked for both sexes with children exhibiting a mean linear growth velocity z-score that is negative in value. Click again please, maybe one more time okay. And the percentage of growth faltering show approximately 26 percent of boys and 36 percent of girls experiencing faltering under the age of 6 months. And these rates are consistent for the first two years of life, you'll see there, with the percentage of experiencing growth faltering decreasing to 67 percent later in life. These findings of a high proportion of linear growth faltering in the first two years of life are consistent with the literature, but also important to note that faltering persists in a smaller proportion of children as after the age of two. Growth rates expressed as a lean growth velocity z-score were significantly... so the boxes in the blue you'll notice that they were significantly worse for girls under the age of two compared to boys.

Next slide

So what about those who are stunted? So they have a height-for-age less than minus 2 at the outset of a growth interval. Do they differentially experience faltered growth? And in our data a substantial proportion of children had a low growth velocity, but were not yet identified as being  $Z < -2$ , because they had not yet reached the height-for-age  $Z$  of less than minus 2. Chris could you please click? Yes. So approximately 30 percent of children less than 24 months of age who were not identified as stunted at the beginning of the interval experienced a low growth velocity  $Z$ -score of less than  $-2$  in the coming year. You could click again... but also worryingly in our data is even those who are stunted... identified as stunted are experiencing further growth faltering. We see this at rates of 18, 27 and 31 per cent for children under 6 months, 6-11 months, and 12-23 months of age, respectively. One sixth of the child population, regardless of stunting status, are experiencing low growth velocity after two years of age. And this reflects faltering patterns in those who were not previously stunted, and then further faltering in those classified as stunted.

Next slide please

So Aim 2 sought to identify antecedent risk factors associated with this this linear growth faltering.

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The methods that we undertook for this work included age-stratified analyses, and the reason that we conducted age-stratified analysis was to reflect the developmental or cognitive changes, and also the feeding changes that occur that are important at different stages in a child's early life. And initially we conducted bivariate analyses using logistic regressions to assess relationships between each risk factor and the outcome of interest, which is linear growth velocity  $Z$  under  $-2$ . We adjusted these estimates for clustering given the design. And finally multivariate logistic regression models for fit with select risk factors, and examining their relationship with linear growth velocity  $Z$  under  $-2$ . And these robust estimates of standard errors were computed for this and the final regressions were also adjusted for clustering and month of age at the outset of  $Z$ .

Next slide

So as Keith mentioned, we've collected a range of factors at different levels, the community, household, and individual, and using these factors as well as the UNICEF Framework for Undernutrition, this is what guided the selection of risk factors in our analyses.

Next slide

Just to revisit this slide, I just want to show where the risk factors were or rather when the risk factors were measured in relation to the growth intervals. So risk factors were measured at time point 1.



Next slide

Okay, so for these ... the next set of graphs that I'm going to show you, I'm just going to illuminate what you're going to be seeing, so that you can follow along. What you see on the left hand side of the graph are the different risk factors that were considered in the final models, and the horizontal lines are the confidence intervals, and the dots or diamonds are the odds ratio estimates. And click please... so these are risk factors at the individual...click again please ... household and ... click again...at the community level. So for children under six months at baseline... click please... we see a HAZ about the WHO standard median, maternal short stature, and increased maternal parity to be associated with an increased odds of growth faltering, and WHZ greater than the WHO standard median, so children that are not wasted. And maternal education, access to health facilities in the past 12 months, and being a resident of a ward with paved roads was associated with a decreased odds of growth faltering.

Next slide

At 6-11 months of baseline... click please... we see that HAZ greater than the WHO standard median was associated with odds of faltering, and again we see that the WHZ score greater than the WHO median, maternal education which is a higher maternal education compared to lower maternal education or none, access to health facilities in the past 12 months, as well as increased wealth, was associated with decreased odds of faltering.

Next slide

So for the 12-23 months age group at baseline, we see that being a girl, maternal short stature, and wards with electricity grids being associated with an increased odds of faltering, and a WHZ score remains consistent with a decreased odds of growth faltering: high maternal education and receipt of immunizations... child immunizations associated with a decreased odds of growth faltering.

Next slide

For the 24-35 months age group, we see the HAZ above the whole standard median and material short stature again are associated with increased odds of faltering, and consuming greater than five food groups and ... that is amongst children... and increased wealth were associated with decreased odds of growth faltering.

Next slide

At the 36 -47 months age range, we see HAZ greater than the WHO standard median versus below maternal dietary diversity consumption of greater than five groups and maternal... mothers deciding on child health care versus not was associated with increased odds of faltering. I would take those last two points with a grain of salt as you can see the very large confidence intervals, and possibly instability of those estimates. And then being closer to

markets, residing in wards with roads and schools were associated versus not ... were associated with a decreased odds of growth faltering

Next slide please

And finally in the 48-59 months group, we see that a HAZ greater than the WHO standard median and the practice of open defecation being associated with increased odds of faltering, accessing health facilities in the past months versus not and then certain age... sorry caste group being associated with a decreased odds of faltering compared to a higher caste group, which was an interesting finding.

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So an important finding in this work, as stated, is that risk factors do vary with age, and while the risk factors studied have been shown to be associated with stunting, most studies don't necessarily identify at which age specific factors might play an important role versus others, because we're not undertaking typically age-stratified analyses, and we are focusing on attained growth measure. Also, you will note that the number of factors identified by the study substantially decreased with age, like the number of risk factors. And factors more proximate to the child and mother play more important role early in life, by age three we see factors reflecting a child environment and social positioning rising in importance. Girls versus boys in the first two years of life were consistently associated with a higher odds of faltering, even if this was not significant at every age group. Maternal short stature was significantly associated with higher odds of faltering in many of the age categories. And finally, WHZ greater than the median was associated with a decreased odds of faltering throughout the preschool period. You should also note here that you would have noticed that WHZ about the WHO standard median was associated with an increased odds of faltering and, while there may definitely be regression to the mean occurring when we broke out the children into quartiles of growth, it's appeared that every quartile of growth children were similarly decelerating in their growth and so this phenomenon was not solely noted for children at the ends of the distribution.

Next slide please

With all studies, we have you know limitations and strengths, and age attribution is ... acquisition just you know ascertaining what is the age of the child is rather difficult in settings where birth registries are not present. And so, you know, we did undertake training to do the best we could with children who might not have had any kind of birth certificate or child health card. There's always issues with measurement error in studies that are focused on anthropometry, while we did standardize and train every year our data collectors, you know, there's always issues that can arise with measurement error. We didn't collect certain important risk factors that we would have liked, so like small-for-gestational age and birth weight, and then there's the issue of regression to the mean with these kinds of studies to have two points where we're measuring anthropometry. And the strengths of the study include longitudinal design, you know the annual assessment of growth, that there's a range of risk factors, and that we're able to establish temporality, and also that we offer a pragmatic but

novel growth reference that covers the entire preschool age range with the recognition that of course, you know, it would be great if an existing reference already was available to us, but for the now, this could be potentially used to estimate faltering in the population.

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And this work, you know the slide is just to say that this work contributes to ongoing discussion, debates and then recent calls to rethink our approach to measuring linear growth and the use of stunting as an indicator to evaluate program success.

Next slide

And as take-home points, I wanted to just highlight the importance of maternal stature in our findings, and it's supportive for [ ] to take a life cycle approach to interventions designed to improve nutrition, especially child nutrition, but also maternal nutrition. And linear growth faltering in the Terai, in this population in Nepal there exists an apparent relationship between wasting and linear growth which... and Andrew has shown in his slide ... there's a high prevalence of wasting in this region and it begs further investigation to see... to understand the relationship between wasting and stunting in the Terai. A distinction ought to be made between low growth velocity and growth faltering and then stunting.

Click please

And I just want to say that, you know, we're not necessarily advocating to not measure stunting entirely or do away with it, but to consider extending our investments to include a second measure of linear growth, to examine population level growth faltering. And maybe refocusing our efforts on measuring a dynamic growth interval may enable some of us in the public health nutrition community to identify the age and severity of linear growth faltering, and through this identification, also assess risk factors associated with these low growth velocities. And you know potentially hypothesize and test the effect of interventions that are timed, and that are evidence-based just to evaluate the sufficient intensity or even the duration of these interventions to achieve a normal improved linear growth velocity.

Next slide

So these are just acknowledgments of the really wonderful large team in Nepal that was very much responsible for collecting all the data over the years. They're a solid group of researchers and data collectors, and brought a lot of important insight into our work.

Next slide please

And finally, it's just a long list of people that we are thankful to and we had ... as they are all sort of moved on now, but we had a very strong research team in Nepal that led up this work, and then great partners on the ground including New era, NTAG. And then we have our university collaborators, including the Tufts team, and then NNIPS which is a Hopkins... part of the Hopkins team. And I do want to recognize USAID for funding this work, as well as additional support that I received personally for some of the work that I did during my

dissertation to support these analyses. So thank you very much and, you know, this is where we are. It's a new piece of work ... or develop you know evolving piece of work, and we'd love to hear your feedback and comments on what we've presented today, and thoughts. So thank you again and thanks Chris for helping with the slides.

Keith West

Swetha thank you very much, and Andrew thank you for these presentations. I've been watching the chats and the Q&As, and some common themes have emerged that can probably be quickly addressed. One question relates to the causes of stunting and across those multiple influences from the community to the individual levels. We point out that what we're showing in this webinar is really to illustrate what can be examined and done to identify groups of children who are at risk of subsequent growth faltering, and bring.... It would be another webinar to talk about what the potential causes are, but this offers another option for identifying children who are at risk of stunting, both those that are stunted, but importantly, those who are not yet classified as stunted. A question arose around this whether there are other countries pursuing this approach. Not to our knowledge at a national level. It does require a second measurement, and so, we would encourage... we think that this is an illustrative example of what can be done when a subsequent paired measurement is added to an existing survey, to go back approximately a year later, and adjust, annualize that increment to look at how these patterns exist across the ages in children. A few other observations are that populations are in a state of decline and pause. There's a there's a salutatory behavior in terms of how children grow and in terms of apparently how populations are changing with respect to their burden of stunting. And it's important to recognize these pauses and to look for innovative ways that may help us move off of levels of stunting that don't seem to be changing over a period of a couple of years. It may also be that the next 10 percent decline in stunting may be a little tougher than the previous 10 or 15 percent, as the prevalence goes down, the complexity of the remaining cases that are in a population may be a little bit more difficult to tackle. So, it's going to require a broader set of initiatives. There is ... just to note what Dr. Manohar was pointing out, that this is a novel growth reference that covers the entire preschool years to provide annualized growth velocities of what might be considered normal and abnormal, as a tool for countries to pursue this approach for assessing growth faltering and risk factors. Another potential advantage is one Dr. Thorne-Lyman brought up about the advantages of looking at...about some of the limitations of prevalence of stunting that to recognize that there are children above minus two z- scores height-for-age who are going to decelerate in their growth in the coming year, perhaps in route to becoming a case of stunting as we classically define it. And so that that is basically a misclassification of our epidemiological approaches, and this offers a way to start to understand what the extent of decelerating growth is even for children above that z-score. Finally, the risk factors that are identified are illustrative. Many more factors that are available in the literature and that people have been writing about and studying about, from diet to biomarkers, to just a whole range of factors can be assessed at the beginning of an interval to do a better job in identifying groups who are going to be at high risk of low growth velocity in the coming year. So those are some further thoughts on questions that have ... that have arisen. Patrick have you been keeping tabs on the Q&As at all? Have you seen any others that that are orthogonal to what I've just brought up or Andrew?

Patrick Webb

I think I have been answering as many as I could in text. I would defer to Andrew and Swetha. I know Andrew have been looking at them some of them.

Keith West

Good. Andrew that there was a couple there addressed to you.

Andrew Thorne-Lyman

Yes, I think [Ramyra] had a great question or a great point, you know, which was, you know, just thinking about... thinking about us as a public health or a public nutrition community, you know and the fact that a lot of ... you know... in the conceptual framework for malnutrition, you know, it sort of separates things out into the proximate causes of malnutrition, and then some of the underlying causes. And just raising this question of, you know, how do we as a public health... public nutrition community, you know, start to think about addressing some of these underlying causes? And I would say that probably that understanding them is a good first step. And one of the limitations of our present approaches to looking at risk factors is just that, as I said, it's just that the content of the surveys that we have seldom, you know, is able to capture some of these things. You know like for example, in the Terai women's status? You know, how do you measure that? We are starting to get some good tools around, you know, gender relations, and the [] is a great tool to start looking at some of these things, but we don't have, you know, great tools for measuring some of these things that could be extremely important to ... in terms of being as potential causes of malnutrition. And so when we see something like maternal education driving the prevalence of stunting, you know, yes that's important and that's probably correlated with a lot of other things that go along with maternal education, related to women's power and ability to negotiate things within the household, and ability to sort of act on some of these nutrition education interventions, etc. There were a couple questions Swetha about electricity and the finding on electrification that you might ...

Swetha Manohar

Sorry, I'm typing some answers to those things. Yes, that was an odd finding to be very honest. And part of it might be that those that were living in a ward with electricity... so we saw for example... depending on the VDC that there were certain... that there were... I don't know how to explain it ... that those people living in wards with electricity grids had a higher proportion of stunting, and that may or may not have anything to do with... I don't know... but we did see higher growth faltering in those VDCs, so I'm not able to explain it to be very honest, but it was an unexpected finding and I will admit to that. There's also a lot of questions that I see about... there's multiple things. One was just discussing again that there were some clarifying questions to discuss the difference between stunting and linear growth velocity, which just to reiterate you know: stunting is being short for one's age at one point in time measured at one point in time, and low growth velocity or linear growth faltering in the way that we're defining it, is just having a slowed rate of growth. And the other question that I was just typing out was to [Saskia] who was asking why there were limited factors or such fewer factors or

risk factors as the children age and to reiterate in terms of our analytic approach, we did examine bivariate associations first, and it was interesting that as children aged, fewer risk factors, especially those most proximate to the child, were associated with faltering, even at the bivariate level. And so often many of those risk factors other than those that we determined to maintain in our model regardless, like for example sex, were not included in the final model. And so, it is something to note that there are fewer factors associated with growth faltering as children age, but they have much more to do with the environment in which the children ... a child exists. There's a lot of questions, I'm not able to focus on all of them at one time, but maybe I could keep typing some of these answers, unless Keith you see something that I can particularly respond to.

Keith West

So I think you're doing a pretty good job. The questions are really interesting ones, and we may be able to follow up with respondents and those who are around the table here. We are coming to a close... Swetha?

Swetha Manohar

From Simone which talks about... asks, you know, how does the findings from the last study associate with growth faltering maybe help to inform some of the flattening of the stunting prevalence observed in Andrew's presentation? And I think you know that might be an important question, especially for those of us ... really in the community here that are doing... are involved in interventions, and I think perhaps in terms of informing that flattening of stunting prevalence, what maybe some of these findings do is to show the importance of different risk factors at different age groups, and that there is, you know, a way that if programs are assessing or hope to decrease faltering of growth and before a child is stunted, that perhaps, you know, this gives insights as to what risk factors are associated with that modifiable factors that can be targeted, but that also, you know, if you want to see how a population is doing in terms of reduction of just inadequate growth, that this could be a measure, you know, at time point 1 and four or five years later, if there has been a lot of interventions addressing some of these risk factors to see improvements. Yes

Keith West

I would just add that we've focused here on the antecedent risk factors to a subsequent growth performance, but risk factors can also - if countries pursue this approach - can of course assess those risk factors at the end of a growth interval which can capture some of the exposures, and stresses, and influences during a year of varying growth velocity that can feed into the epidemiological thinking in a country, and perhaps provide further insights into how there may be some new ideas, new approaches to preventing growth faltering that can lead to stunting.

We're delighted with the questions that are coming in and the interest. The growth references are being prepared for a paper to be submitted. So expect to see that hopefully coming out in the not too distant future. That may be a useful tool for those interested in this approach. And we really appreciate the interest that has been shown and those who have attended. Professor Webb, would you like to offer any closing comments?

## Patrick Webb

No other than thanks to all participants. Many are having to leave now, and thanks to the panelists. Excellent wide-ranging and thought-provoking presentations. Thanks to you Keith and to all involved in this important webinar. And look out for the next one in the series coming up in two weeks relating to Malawi's experience in setting up its own national dietetics program, and what was necessary to make that feasible and a success. Much more information on the [nutritioninnovationlab.org](http://nutritioninnovationlab.org) website, including papers and recordings of previous webinars, as well as this one, when it gets posted soon. And thank you all, and hope to have you involved again. Take care and be safe and well.

## Keith West

Thanks again



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This document was produced for the U. S. Agency for International Development. It was prepared under the terms of contract 7200AA18C00070 awarded to JSI Research & Training Institute, Inc. The contents are the responsibility of JSI and do not necessarily reflect the views of USAID or the U.S. Government.