Midday Meals as an Early Childhood Nutrition Intervention: Evidence from Plantation Communities in Sri Lanka

Udeni De Silva Perera (✉ udeni.perera@monash.edu)

Monash University <https://orcid.org/0000-0002-8859-926X>

Brett A. Inder

Monash University

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Midday meals as an early childhood nutrition intervention: evidence from plantation communities in
Sri Lanka

Udeni De Silva Perera and Brett A. Inder

Udeni De Silva Perera- Corresponding Author

Department of Econometrics and Business Statistics,

Monash Business School

Monash University, Australia

Brett A. Inder

Department of Econometrics and Business Statistics,

Monash Business School

Monash University, Australia

Abstract

Background: High rates of child malnutrition are a major public health concern in developing countries, particularly among vulnerable communities. Midday meals programs can be effective for combatting childhood malnutrition among older children. However, their use in early childhood is not well documented, particularly within South Asia. Anthropometric measures and other socioeconomic data were collected for children below the age of five years living in selected Sri Lankan tea plantations, to assess the effectiveness of midday meals as a nutrition intervention for improving growth among young children.

Methods: The study exploits a natural experiment whereby the provision of the midday meals program is exogenously determined at the plantation level, resulting in comparable treatment and control groups. Longitudinal data is regularly collected on heights and weights of children, between 2013-2015. Standardized weight-for-age, height-for-age, BMI-for-age and weight-for-height are calculated following WHO guidelines, and binary variables for stunting, wasting and underweight are constructed. All modelling uses STATA SE 15. Random-effects regression with instrumental variables is used for modelling standardized growth variables whilst random-effects logistic regression is used for binary outcome variables. Robustness analysis involves different estimation methods and subsamples.

Results: The dataset consists of longitudinal data from a total of 1279 children across three tea plantations in Sri Lanka, with 799 children in the treatment group and 480 in the control group. Results show significant positive effects of access to the midday meals program, on the growth of children. A child with access to the midday meals intervention reports an average standardized weight-for-age 0.03 (± 0.01) and height-for-age 0.05 (± 0.01) units higher than a similar child without access to the intervention. Importantly, access to the intervention reduces the likelihood of being underweight by 0.45 and the likelihood of wasting by 0.47. The results are robust to different model estimations and across different subsamples by gender, birthweight and birth-year cohort.

Qualitative data analysis suggests a high viability of implementing similar programs within tea plantations in Sri Lanka.

Conclusions: Midday meals programs targeting early childhood can be an effective intervention to address high rates of child malnutrition, particularly among vulnerable communities in developing countries like Sri Lanka.

Keywords: Child growth, nutritional status, midday meals programs, plantation community, Sri Lanka, weight-for-age, height-for-age, underweight, wasting

Background

Child malnutrition and mortality are key health issues in many developing countries. According to UNICEF/WHO/World Bank joint estimates, in 2018, 149 million children below the age of 5 were stunted while over 49 million children were wasted. More than half of all stunted children live in Asia [1]. Since the signing of the Millennium Declaration in 2000 Sri Lanka has made good progress in reducing child and maternal mortality. However child morbidity remains a key concern [2,3]. Official statistics on child malnutrition also indicate significant regional variations at sector and district levels [2,4–6].

The tea plantation community in Sri Lanka suffers from a long history of discrimination, neglect and deprivation [7]. Resident plantation systems were introduced to Sri Lanka in the mid-19th century, during the British colonial period. Introduced for the cultivation of tea and rubber, indentured laborers were brought to the country from South India, to live and work within plantations. This established the first Indian Tamil communities in Sri Lanka. Considered as outsiders to the country, significant language barriers and estates typically located in inaccessible mountainous terrain, resulted in Indian Tamil plantation communities facing significant social and geographic isolation [8–10]. Plantation communities were granted citizenship rights in early 1990's following years of

political struggle, and today represent close to 5% of the Sri Lankan population [11]. Given its sizable magnitude and unique characteristics, plantation residents are recognized as a third sector, separate from the traditional urban and rural sectors in Sri Lanka. Existing literature points to poverty, poor health, malnutrition, lack of education opportunities and alcoholism to be among the major issues faced by a majority of the plantation community [12]. According to the 2016 Demographic and Health Survey (DHS), over 30% of children living within the plantation sector suffered from stunting whilst close to 30% were also underweight, prevalence far higher than the national averages of 17% and 20% respectively [2]. Children below the age of five years are particularly vulnerable to malnutrition given that the most crucial growth in humans occur within this period [13].

Malnourished children can grow up to be less productive adults, contributing to a continuing cycle of chronic poverty. It thus becomes imperative to disrupt the cycle of malnutrition within the early years of life.

The plantation sector of Sri Lanka has attracted many intervention programs aimed at improving living standards of plantation communities [14,15]. Some well-known nutrition interventions targeting children are the *Thripasha* nutrition supplementation program, school milk program and the school midday meals program. Apart from the *Thripasha* program which provides a protein-based cereal to children above the age of six months, most other nutrition interventions target children of school-going age [16,17]. This study considers the possibility of using midday meals programs as an effective mechanism for combating early childhood malnutrition. Exploiting a natural experiment where a midday meals program is being gradually rolled out across a number of tea plantations in Sri Lanka, we use longitudinal data, to assess the impact of access to this midday meals program which targets children below the age of five years.

The midday meals program studied here is run by a major charitable foundation which works on improving living standards of plantation communities in Sri Lanka. Initiated in 2008, the program has been systematically introduced to tea plantations belonging to two major regional plantation

companies (RPCs). Whilst RPCs account for around 25% of total tea/rubber plantation workers in Sri Lanka, these workers and their families are considered to have better living conditions and facilities than most, due to stronger corporate oversight of these companies. This suggests that any potential improvements achieved through the targeted intervention with this sub-population could potentially be even greater with the broader, more disadvantaged plantation community.

The midday meals program is implemented through child development centres (CDC) in tea estates. Given the female-intensive labour structure of the tea industry, child development centres have a long history within tea plantations. The centres provide childcare services to laborers who work in the plantations and have children below the school-going age. The midday meals program was designed to provide a balanced daily midday meal to children at these centres. Whilst registration at child development centres is limited to plantation employees, plantation employment is noted to have characteristically low barriers to entry/exit given the consistently high demand for manual labour within the industry. Therefore, in plantations that run the midday meals program, the program is also considered to have low barriers to entry for plantation children aged six months to five years, living within the plantation.

This paper focusses on exploring the impact of program access on child growth using a treatment-control analysis by sampling tea plantations which host and do not host the midday meals program. The paper contributes to the public health literature in a number of ways. First, given the popularity of midday meals as a nutrition intervention among school-going children, we explore the potential for its use in early childhood, which has not attracted much research within South Asia. Second, as these types of interventions grow in popularity and are widely adapted across developing countries, it is important to investigate the extent of their effectiveness in improving nutritional and growth outcomes of vulnerable children. In addition to the quantitative analysis, we also use qualitative data to broadly assess how feasible the implementation of similar programs is, within tea plantations in Sri Lanka.

Methods

Study setting and design

Tea plantations belonging to one regional plantation company (RPC) were selected as the sampling frame for the study. The RPC managed a total of 12 tea plantations, five of which ran the midday meals program as of June 2015. The program was planned to be rolled out across the other seven plantations in due course. All plantations were located in close proximity within the Thalawakale region of Sri Lanka. This setup can be considered as a natural experiment where a group of plantations with and without the midday meals program are compared. Longitudinal data was collected on the heights and weights of all children below the age of five years living in sampled plantations. Available demographic data was also collected for the sampled children together with institutional level data. Sample sizes required for the treatment and control groups were calculated following the standard methodology for sample size determination in field surveys [18,19], using the formula, $N = \frac{p(100-p)z^2}{E^2}$, where E is set at 5% and z at 95%. Taking a conservative approach to computing required sample size, we assume 50% coverage of the midday meals program among children within the sampling frame. This gives a minimum sample size of 322 for the treatment and control groups. Simple Random Sampling using the Order Sampling approach was used to pick the sample of treatment and control plantations [20]. The sampling procedure resulted in 3 plantations (i.e. 2 treatment and 1 control) being selected with an overall sample size of 799 children within the treatment group and 480 children within the control group. The survey was conducted in June 2015, with a follow up qualitative survey conducted in April 2016.

The main source of anthropometric data and program attendance data was through midwife and CDC records. Consent for the provision of this data was obtained from plantation midwives and the child development officers (CDO) who head each CDC. Midwives and CDOs were also interviewed in order to collect institutional level data, information on the general health status of plantation children and details of the implementation and management of the midday meals programs. A

housing quality checklist questionnaire was used to assess the general housing quality in each of the visited plantations, using a convenience sample of households.

Ethics Approval and Data Quality Procedures

Given the nature of the survey which deals with growth information of children below the age of five years, necessary ethics approval was obtained from several different institutions: the Monash University Human Research Ethics Committee (MUHREC) and the Plantations Human Development Trust - the main government authority overseeing human capital within the tea industry in Sri Lanka. Approvals were also obtained from the management of both the charitable foundation implementing the midday meals program and the regional plantation company managing the plantations where the survey was conducted.

As direct participants of the study, written informed consent was obtained from all midwives and CDOs interviewed. Parental consent was not required by MUHREC or by the Sri Lankan authorities, as children were not directly interviewed or studied during the survey. The study relies on secondary data routinely collected and maintained by midwives and CDOs for health monitoring purposes. Complying with their approval and privacy protocols, this data was released by them in an appropriate non-identifiable format. Accordingly, historical data on children's weight and height measures were provided to us in a non-identifiable format by the midwives and CDOs. Survey instruments including the questionnaires for interviewing the estate midwife and CDOs were translated to Tamil and pre-tested through a pilot survey carried out in April 2015.

Data

Anthropometric data for all children below the age of 5, living in sampled plantations was collected for the period January 2013-June 2015. Data consisted of an unbalanced panel of body weights (*kg*) and heights (*cm*) for children recorded by the estate midwife or CDOs. Weights were measured and recorded monthly while the heights were measured and recorded quarterly. Since data was only available for the period January 2013- June 2015, early-age weight and height measures for older

children (3-5 year old's as of 2015) were not available. For the purposes of analysis, each child's panel was considered starting from the first available body weight measure for the child. Impacts of this truncation of sample data is investigated under the robustness analysis. To match the monthly frequency of weight measures, missing monthly heights were imputed using cubic spline interpolation. Children's body mass index (bmi) was calculated using their weight and height at each time point.

Z-scores for the weight-for-age (*zwei*), height-for-age (*zhei*), bmi-for-age (*zbmi*), and weight-for-height (*zwfh*) were obtained following the methodology outlined by the WHO [21], using *WHO igrowup* macros. Binary variables were also constructed to identify whether a child was underweight, stunted or wasted in any given time period, by considering whether *zwei*, *zhei* and *zwfh* fall below -2.00. These binary variables (*underweight*, *stunted* and *wasted*) together with the *zwei*, *zhei* and *zbmi* are used as dependent variables in models.

Given the primary intention of the study is to assess the effectiveness of the nutrition intervention and to prescribe methods for improvement and further adoption of the program, it is important to use the globally accepted WHO methodology when constructing the dependent variables in the models [21]. However, to counter any criticism arising from the use of WHO standardization of growth measures in critically impoverished communities, in-sample standardized growth measures are also incorporated into the models as control variables. Accordingly, the first weight/height measure for each child and their birthweight are standardized using in-sample median and standard deviations.

Other child level variables collected included date-of-birth, gender, birthweight and ethnic group. A CDC level variable indicating the physical condition of the CDC (old, upgraded or new) is also included in models. The treatment variable used in modelling is a time-invariant binary variable (*Trt*) identifying whether a child lived in a treatment or control plantation. Hence *Trt* identifies access to the midday meals program.

Empirical strategy

Identification of the treatment effect hinges on exploiting the natural experimental setup arising from the staggered introduction of a midday meals program across similar tea plantations located in the same locality and managed by the same regional plantation company. The broad assumption here is that the plantations belonging to the treatment and control groups are generally similar – an assumption whose validity will be critically evaluated. Validity is also supported by relying on random selection of the specific plantations to include in the sample, from the populations of treatment and control plantations. The following model is used to model the treatment effect:

$$H_{i,t} = \alpha + \beta_1 Trt_i + \beta_2 X_{i,t} + \beta_3 Z_i + \varepsilon_{i,t} \quad (1)$$

The subscripts i and t refer to child i at age t (in months). H represents a set of dependent variables which measure child growth. These include the standardized weight-for-age ($zwei$), height-for-age ($zhei$), bmi-for-age ($zbmi$) and binary variables *underweight*, *stunting* and *wasting*. The Vectors X and Z include time-varying and time-invariant child-level variables respectively, while Trt represents a binary variable indicating whether a child belonged to the treatment or control group. We assume all children in the treatment group have access to the midday meals program irrespective of the employment status of their parents/guardian. This assumption is deemed valid given the low barriers to entry to plantation employment throughout the year. No children in the control group have access to the program. Models for $zwei$, $zhei$ and $zbmi$ are fitted using a random-effects instrumental variable specification while models for *underweight*, *stunting* and *wasting* are fitted using random-effects logistic specification. All models fit robust standard errors. Finally, ε is an idiosyncratic error term.

Different variants of the above model were also fitted, in order to establish the robustness of the results. These include modelling by gender, birthweight and birth-year cohort, in order to establish

program equity, and using different estimation strategies (e.g. Generalized Least Squares Random Effects) to establish model robustness.

The limited number of observed demographic variables could present a challenge in modelling due to possible omitted variable bias. Whilst a fixed-effects specification could have dealt with the issue of unobserved child-level variables, the time-invariant treatment variable does not allow for the use of fixed-effects. Therefore, it is important to address a number of specific concerns regarding the identification strategy.

Possible Endogeneity of Treatment Variable

The treatment has been allocated across the tea plantations within the sampling frame based on managerial decisions about the order of roll-out of the program across plantations. Management report no systematic factors that influenced the decision about order, other than practical/administrative matters. However, a lack of full information about how such decisions were made gives rise to the possibility that our treatment variable may be endogenous if systematic differences between the treatment and control groups exist. As noted above, based on a number of factors such as the tea plantations being located in close proximity to each other, and being managed by the same plantation company, it may be reasonable to assume that the treatment and control plantations are generally similar. Baseline data can be used to check the validity of this assumption. Since the primary focus of the study is on the growth of children below the age of 5 years, we use weight records of children up to 6 months of age across the treatment and control samples to explore the baseline growth of children in the two groups. Given that the midday meals intervention is applicable to children above the age of 6 months, the growth of children when they are between 0-6 months of age provides a suitable baseline for comparing the general growth patterns between the control group and the treatment group prior to the treatment.

The histograms of weight-for-age zscores (*zwei*) in the 0-6 month age category across the treatment and control groups, together with the standard normal distribution curve, are presented in Figure 1.

According to this, the distribution of *zwei* appear to be closer to the standard normal distribution within the control group than the treatment group. The two-sample Kolmogorov-Smirnov test for equality of distribution functions, rejects the null hypothesis of equality in distribution between the treatment and control groups (Combined K-S: 0.22, $p < 0.000$). These results suggest that children in the treatment group may be starting at a relative growth disadvantage compared to children in the control group, at the baseline.

A number of methods are used to overcome potential endogeneity of the treatment variable, the most significant of which is to control for measures of past growth, using a lagged dependent variable ($H_{i,t-1}$ in equation (1)) as a control variable in the models. We also use other measures of past growth (birthweight, first recorded weight and height) as control variables. Proxy variables are also included to control for important unobserved time-invariant factors, where applicable. Together these measures should account for any significant time-invariant factors that may drive systematic differences between the treatment and control samples with respect to the growth of children. In addition to this we also include proxy variables to control for possible time-varying factors which could also cause systematic differences between the treatment and control groups. Added together, these methods provide reasonable confidence that we are capturing a causal effect with the treatment variable, having overcome any possible significant bias in our identification strategy. To provide another level of detailed reassurance about this, we next give details of the main relevant unobserved time-invariant and time-varying factors whose impacts are accounted for through this analytical approach.

Figure 1: Histogram of weight-for-age zscores in the 0-6 month age category in treatment and control groups

Time-Invariant Unobserved Variables

The first characteristics to consider are the general living standards and facilities in the estates. Systematic differences in these characteristics across treatment and control groups could, if not modelled, find their way into the model error, and be correlated with the Treatment indicator variable, resulting in an endogenous treatment variable. In addressing this concern, we make use of housing quality data collected as part of the survey. A housing quality checklist was used to collect data on the average quality of housing within each plantation. Principal Components [22] was then used to construct a housing quality index. Models incorporating the housing quality index as a control variable show very similar results to the main models fitted. The housing quality index was statistically significant and positive in the weight-for-age model but not significant in height-for-age and BMI-for-age models. The results broadly suggest the similarity between treatment and control groups with respect to general living standards and facilities.

Household income and food security are also not observed in our data, and these could also vary with the treatment and outcome variables, leading to an endogeneity risk. With regards to

household income, prior research indicates that most plantation families tend to be employed within the tea industry, mostly working in their resident plantation or similar plantations in the area [8,22]. Daily wages paid to plantation workers are well regulated, consistently low and stagnant over time [8]. These factors coupled together with limited access to other forms of income through non-plantation work [8,22] suggests that the average household income would not vary much over time and across the three study plantations. Given the stagnant nature of income in the short run, using past measures of growth (i.e. the prior period's growth, first weight/height measure on record) would account for the impact of household income on the growth of children and effectively remove any bias created as a result of its omission from the model.

Related to incomes is food security: given the generally low incomes and high levels of poverty within the rural and plantation sectors [23], there is likely to be a strong link between household income and food security. Therefore, the arguments above regarding income would largely also apply to food security. However, apart from income, socio-cultural factors could also impact food security due to culturally induced food preferences or aversions. This would pose an analytical challenge if there is evidence to suggest variations in the ethnographic composition of residents across the treatment and control groups. However, given that over 80% of plantation sector residents are from an Indian-Tamil ethnic background [22], it is reasonable to assume homogeneity in the ethnographic composition and hence food preferences across the sampled plantations.

Family economic background and parental education are also unobserved household level variables which tend to be fixed over time [24]. Therefore, it is reasonable to assume that whilst these variables would impact child growth, they would not cause any systematic differences between treatment and control groups. Nevertheless, it is important to control for as many of these effects as possible. Birthweight is an example of a variable which can be used as a proxy to reflect the general socio-economic background of children as it impacts their growth. Apart from the rare occasion of a genetic/medical complication which impacts a child's in utero growth, birthweight is usually a

consequence of the nutrients that the mother receives during pregnancy. Past studies have established the close relationship between maternal and child nutrition, including in the plantation sector of Sri Lanka [25]. We can thus use birthweight as a proxy for the general economic background of the child's family, especially around the time of birth.

Potential Time-Varying Unobserved Variables

The level of parental care and general child-care practices at home can have a significant impact on the growth of children. This factor becomes even more pertinent considering the female dominant labour structure and the relatively large household sizes prevalent in tea plantations [23]. A child's health and nutrition during early infancy has a strong dependence on parental care. Even though there is little evidence to suggest that this would differ significantly between treatment and control plantations, not accounting for parental care received by the child may potentially bias our results. Therefore, it is important to control for this effect. In most countries, children below the age of 5 years are required to be regularly checked by a qualified midwife. Sri Lanka has similar practices, whereby children below the age of 5 are regularly monitored and parents of children living in identified vulnerable communities are strongly advised to visit a midwife, for check-ups on a monthly basis. Given this background, regularity of monthly midwife visits is considered as a possible proxy which would reflect the level of parental/guardian care and attention received by the child. Accordingly, a running proportion is constructed to capture the proportion of midwife visits actually taken compared to the number available, for each child i in each time period (months) t ,

$$mwv_{it} = \frac{\text{Number of midwife visits since first weighing}_{it}}{(t - firsttime + 1)} \quad (2)$$

firsttime is the age at which the first measure of the child's weight occurs within the surveyed period. The proportion is taken as 1 at the point of first measure on record, for every child. The variable *mwv* is used as a control variable in all models, as a proxy for parental care.

The above details the methodological and intuitive framework used to overcome potential issues around identification in our models. Whilst it is possible that other unobserved variables beyond those hypothesized may exist, it is unlikely that these would cause any sizeable systematic differences between the treatment and control plantations that affect the estimates of treatment effects.

Inter-plantation migration due to midday meals program

A couple of other possible sources of bias remain to be discussed. First, if families are able to relocate between plantations, one could imagine some families relocating based on the availability of the midday meals program. In practice, this is considered to be highly unlikely, given the generally landless status of plantation residents [22]. Plantation residents are provided housing and other amenities through the plantation management and their right to the homes they live in is partly determined by several generations of a family living and working within the same plantation [8,22]. The freedom to relocate between plantations is considerably low.

Sample Truncation

Given the time window in which anthropometric measures were collected (i.e. January 2013- June 2015), non-random sample truncation is a possible concern in the study, as the window of observation does not allow for observing early measures of weights and heights for older children in the sample. We include the child's birth year and age as independent variables in order to account for this effect. Further robustness tests are also carried out to determine the effects of non-random truncation/ attrition using sample attrition weights in models [26].

Statistical Analysis

De-identified height/weight data provided by the midwives and CDOs were entered to Microsoft Excel 2013 together with other child and CDC level variables. Data was then imported to STATA SE 15 and the dependent variables were constructed using the *WHO igrowup* macro.

Instrumental variables

As indicated above, past measures of growth (i.e. lagged *zwei*, *zhei* and *zbmi* etc.) are used as controls in the model in equation (1), in order to account for some of the unobserved time-invariant factors such as HH income and food security. However, in *zwei*, *zhei* and *zbmi* models, this poses an additional analytical issue, as the lagged dependent variable becomes an intermediate variable in the causal pathway between the treatment and dependent variables. An intermediate variable can be defined as a variable which forms part of the causal pathway in the relationship between a treatment and an outcome. As a result, part of the treatment effect may be masked by the intermediate variable. In addition to this, there may also be other unobserved variables which may impact both the present and previous period's growth which could also bias results. For these reasons, it is necessary to instrument for the lagged dependent variable in *zwei*, *zhei* and *zbmi* models.

The instrumenting strategy implies a first-stage equation of the form:

$$H_{i,t-1} = \delta_1 + \delta_2 IV + \delta_3 X_{i,t} + \delta_4 Z_i + u_{i,t} \quad (3)$$

where *IV* refers to the set of instruments used in each model, vectors *X* and *Z* represent time-varying and time-invariant child-level variables used in equation (1) and *u* is an idiosyncratic error term. Considering the instruments used, the birthweight and the lagged parental care variable (*mwv_{i,t-1}*) are used to instrument for *zwei_{i,t-1}* in equation (3). Given the sample comprises of children below

the age of 5 years, it is reasonable to assume that the birthweight would be correlated with the $zwei$ in early years, an assumption confirmed by the analysis. It is also reasonable to assume that the relationship between birthweight and $zwei_{i,t}$ will occur via $zwei_{i,t-1}$. Therefore, birthweight can be considered as a valid instrument for $zwei_{i,t-1}$ in the model.

Considering the lagged parental care proxy variable ($mwv_{i,t-1}$), this variable reflects the general history of care received by children. Therefore, $mwv_{i,t-1}$ will also be strongly correlated with $zwei_{i,t-1}$. In addition to this it is again reasonable to assume that the relationship between the lagged parental care variable ($mwv_{i,t-1}$) and the current periods weight-for-age will manifest through the previous months weight-for-age. Therefore, $mwv_{i,t-1}$ can also be considered as a valid instrument for the lagged dependent variable in the weight-for-age model.

With regards to the height-for-age models, $mwv_{i,t-1}$ is again used as a valid instrument for $zhei_{i,t-1}$. A standardized value of the first height on record ($firstzheight$) is also used as an instrument for the lagged height-for-age. Birthweight, standardized value of first height ($firstzheight$) and the lagged parental care variable are all used as instruments for the previous period's bmi-for-age ($zbmi_{i,t-1}$) in the bmi-for-age models.

The validity of the instruments is assessed using the Kleibergen-Paap rk test (for under-identification), Cragg-Donald Wald F Test (weak instrument) and Sargan-Hansen test (over-identification). Test results indicate that the instruments used are valid in the main models. However, they cannot be confirmed as valid in some of the subsample models, likely due to smaller sample sizes. Generalized Least Squares Random Effects (GLS RE) models are fitted in these cases, as a robustness test.

Lagged values of $zwei$, $zhei$ and $zbmi$ are used as control variables when modelling the binary dependent variables *underweight*, *stunting* and *wasting* respectively. However, an instrument variable approach is not necessary in this case as these control variables are not direct intermediate variables in these models.

Results

Descriptive Analysis

Table 1 provides a descriptive summary of the dependent and control variables used in models. The overall sample was balanced with respect to gender: females (51%) and males (49%), and there is no statistically significant difference in the gender-split of the treatment and control groups. Mean birthweight in the overall sample is 2.5kg, while the mean birthweight is slightly higher in the treatment group than the control group (difference is statistically significant). The proportion of low birthweight births is 0.39 in the overall sample, and not statistically different across the treatment and control groups. Looking across the dependent variables, the mean standardized weight-for-age (*zwei*), height-for-age (*zhei*) and BMI-for-age (*zbmi*) is negative in the overall sample, which is further evidence of the generally low growth status of plantation children. Mixed patterns are observed when comparing growth across treatment and control samples, with the treatment group showing better *zhei* than the control group and the opposite pattern observed for *zwei* and *zbmi*. Similar patterns are also observed with respect to the proportions of underweight, wasting and stunting, with the proportion of wasting and stunting seen to be lower within the treatment group, compared to the control group. The mixed patterns further highlight the need for robust modelling in order to detect growth differences across treatment and control groups.

Table 1: Descriptive statistics of the main dependent and control variables

	Total			Treatment			Control		
	N	Mean/ Prop	95% CI	N	Mean/ Prop	95% CI	N	Mean/ Prop	95% CI
Dependent V									
<i>zwei</i>	17214	-1.69	(-1.70, -1.67)	11834	-1.74	(-1.76, -1.72)	5380	-1.58	(-1.60, -1.55)
<i>zhei</i>	10309	-2.01	(-2.03, -1.99)	7581	-1.94	(-1.97, -1.92)	2728	-2.20	(-2.24, -2.15)
<i>zbmi</i>	7780	-0.64	(-0.66, -0.61)	5934	-0.73	(-0.76, -0.70)	1846	-0.32	(-0.39, -0.25)
<i>underweight</i>	17214	0.37	(0.36, 0.37)	11834	0.38	(0.37, 0.39)	5380	0.33	(0.32, 0.35)
<i>wasting</i>	7496	0.16	(0.15, 0.17)	5788	0.16	(0.15, 0.17)	1708	0.17	(0.15, 0.19)
<i>stunting</i>	10309	0.5	(0.49, 0.51)	7581	0.47	(0.46, 0.48)	2728	0.58	(0.56, 0.60)
Control V									
Gender (Male)	1279	0.49	(0.47, 0.52)	799	0.48	(0.44, 0.51)	480	0.52	(0.47, 0.56)
Birthweight (kg)	1148	2.50	(2.47, 2.54)	735	2.54	(2.50, 2.57)	413	2.44	(2.39, 2.50)
Low BW	1148	0.39	(0.36, 0.42)	735	0.38	(0.34, 0.41)	413	0.42	(0.38, 0.47)
Ethnicity (Sinhala)	1279	0.09	(0.07, 0.10)	799	0.11	(0.09, 0.13)	480	0.05	(0.03, 0.07)
Parental care (mwv)	17214	0.87	(0.86, 0.87)	11834	0.85	(0.85, 0.86)	5380	0.89	(0.89, 0.90)

Baseline growth indicators across Treatment and Control Groups

As noted in Figure 1, the treatment and control groups show significant differences in baseline levels of weight-for-age. In this section, we look at the treatment and control groups in more detail. Table 2 provides a comparison of the proportions of *underweight*, *wasting* and *stunting* in the overall sample, 0-6 month and 7-60 month age categories. Based on the higher proportion of *underweight* in the 0-6 month age group in the treatment group, children in the treatment groups appear to have relatively poor growth measures compared to the control group at the baseline. A similar pattern is also evident with the proportion of *wasting*, where a relatively higher proportion is observed within the 0-6 months age category within the treatment group. This pattern however, is not observed with regards to *stunting* at the baseline. When looking at the 7-60 month age category, it is clear that there is a significant worsening in the proportion of children who are underweight compared to the 0-6 month age group, and that the worsening is greater for the control group. In contrast, there is a sizeable improvement in the proportion of *wasting* for both treatment and control groups, with slightly larger improvements in the treatment group. *Stunting* worsens for both the treatment and control groups, with the greater increase in *stunting* being observed for the control group. The worsening of child growth with age, compared to WHO reference populations is a phenomenon often detected in developing countries [27]. However, the results suggest that while children in the treatment group may be starting at a relative growth disadvantage compared to children in the control group, the impact of the midday meals program appears to be helping bridge this early growth gap between the two groups and somewhat slow down the decline in growth with age within the treatment group. More comprehensive models to follow will seek to confirm this observation.

Table 2: Prevalence of underweight, wasting and stunting by age category and group

	Overall [Mean (95% CI)]		Treatment [Mean (95% CI)]		Control [Mean (95% CI)]	
	0-6 mon	7-60 mon	0-6 mon	7-60 mon	0-6 mon	7-60 mon
<i>Underweight</i>	0.23 (0.21, 0.25)	0.38 (0.37, 0.39)	0.29 (0.26, 0.32)	0.39 (0.38, 0.40)	0.12 (0.09, 0.15)	0.36 (0.34, 0.37)
N	1422	15792	917	10917	505	4875
<i>Wasting</i>	0.41 (0.21, 0.64)	0.16 (0.16, 0.17)	0.43 (0.18, 0.71)	0.16 (0.15, 0.17)	0.37 (0.08, 0.75)	0.17 (0.16, 0.19)
N ¹	22	8014	14	6144	8	1870
<i>Stunting</i>	0.43 (0.35, 0.51)	0.51 (0.49, 0.52)	0.43 (0.28, 0.59)	0.48 (0.47, 0.49)	0.43 (0.33, 0.53)	0.59 (0.57, 0.61)
N	147	8151	42	6240	105	1911

¹ Sample size for wasting in the 0-6 month age category is small due to the limited number of height/length records available for children in this age group and used in models

Main Treatment Effects

Figures 2-4 summarize the results of a series of regressions depicting the relationship between the growth status (*zwei*, *zhei* and *zbmi*) of child *i* in month *t* and access to the midday meals intervention. Regressions include all controls discussed above and robust standard errors. The figures depict coefficient estimates and 95 percent confidence intervals. For ease of exposition the figures only report estimates of the coefficients of the Treatment variable (full estimates are provided in tables). The left panel shows the results based on instrument-variable random effects (IV-RE) estimation, while the right panel shows the results using generalized least squares random-effects (GLS-RE). In order from the top, the panels depict results for the full sample, among girls, among boys, among low birthweight children and among normal/high birthweight children. As indicated in Figures 2-4, the IV-RE and GLS-RE results are consistent across all subsamples.

Figure 2 presents the estimated treatment effect on the weight-for-age zscore, in the IV-RE and GLS-RE models. The results show that having access to the midday meals intervention is associated with a statistically significant increase in the weight-for-age zscores, in the full sample, among girls,

among boys and among children having a normal/high birthweight with estimated effects between 0.03 and 0.04 standard deviation (SD) units in IV-RE models and between 0.05 to 0.09 SD units in the GLS-RE models (estimated treatment effects using GLS models will be different to IV-RE as they do not correct for the intermediation effect of the lagged dependent variable).

The treatment effect is not statistically significant among children having low birthweight in the IV-RE model. However, the instrument validity tests report this model to be underidentified, which implies that the GLS-RE estimate would be more reliable in this subsample. The GLS-RE model indicates a statistically significant treatment effect in the low birthweight cohort. However, the magnitude of the treatment effect is clearly smaller for the low birthweight category cohort compared to the normal/high birthweight cohort. The magnitude of the treatment effect is similar for girls and boys. Similar confidence intervals are observed across the samples suggesting that the magnitude of the effect of the midday meals intervention on the weight-for-age zscore is similar across the different cohorts (with the exception of the underidentified IV model in the low birthweight cohort).

Figure 2: The relationship between weight-for-age zscore and access to the midday meals program

Figure 3 presents the estimated treatment effects on the height-for-age zscore, in IV-RE and GLS-RE models. Again, access to the midday meals intervention is associated with a statistically significant increase in the height-for-age zscores, in the full sample, among girls, among boys and among children having a normal/high birthweight. Only marginally significant treatment effects are observed among children having low birthweight (significance at 10%). The estimated effects range between 0.02 and 0.08 SD across the IV-RE models and between 0.02 to 0.09 SD units in the GLS-RE models. The magnitude of the treatment effect is also higher among girls compared to boys.

Figure 4 presents the estimated effect of access to the midday meals intervention on the BMI-for-age of children. The point estimates are not statistically significant in the full sample as well as across the different cohorts. This suggests that access to the midday meals intervention does not show significant impacts on the BMI-for-age of children.

Figure 3: The relationship between height-for-age zscore and access to the midday meals program

Figure 4: The relationship between BMI-for-age zscore and access to the midday meals program

[Figure 2-4 Notes: Regressions are estimated using robust standard errors. The treatment variable is a binary variable equal to one if the child lives in a plantation which runs the midday meals interventions.]

Table 3 presents IV-Random Effects and GLS-Random Effects model results for weight-for-age, height-for-age and BMI-for-age in the full sample. Regressions include all controls including the child's birth year, to account for non-random attrition.

Insert Table 3 here

Table 4 and Table 5 present IV-Random Effects model results by gender and birthweight cohorts respectively.

Insert Table 4 here

Insert Table 5 here

Validity of Instruments

The Kleibergen-Paap LM, Cragg-Donald and the Sargan-Hansen (S-H) tests (for underidentification, weak-identification and overidentification respectively) were carried out to check the validity of the instruments used in the IV models. All three tests confirm the validity of the instruments used in the weight-for-age and height-for-age models fitted to the full sample. The S-H score indicates that the BMI-for-age model is marginally overidentified. However, the observed treatment effect is not significant in both the GLS and IV specifications of the BMI-for-age model. For models fitted in subsamples by gender and birthweight, the instruments were also valid in all models with the exception of the weight-for-age model fitted to the low birthweight cohort (the model is underidentified).

Treatment Effects by Birth-Year Cohort

In the plantations belonging to the treatment group, the midday meals intervention was initiated in 2007. This implies that children born between 2007 and 2009, within the treatment group, would have been the first batch of children to have access to the intervention from early infancy whilst, children born between 2010 and 2012, would have been beneficiaries of a relatively more mature midday meals program. Children born between 2013 and 2015 would have had access to a well-seasoned program, given that the program would have been functional for around 6 years by then. Hence it is interesting to explore possible differential effects for children within these three birth-year cohorts. Figures 5-7 present results of the weight-for-age, height-for-age and BMI-for-age IV-RE and GLS-RE models on these three cohorts.

First, consider the estimated treatment effects on the weight-for-age zscore (Figure 5). Statistically significant treatment effects are only observed in the 2013-2015 birth-year cohort where access to the midday meals intervention is associated with an increase of 0.07 SD on average, in the weight-for-age zscore. The intervention also has a statistically significant positive effect on the BMI-for-age

of children within the 2013-2015 birth-year cohort as indicated in Figure 6, where the intervention is associated with an increase of 0.17 SD in the BMI-for-age zscore.

An opposite pattern is observed in the height-for-age models presented in Figure 7 where the estimated treatment effects on the height-for-age zscore is statistically significant within the two older birth-year cohorts 2007-2009 and 2010-2012. Access to the midday meals intervention is associated with an average increase of 0.05 SD and 0.04 SD in the height-for-age zscore among children born between 2007-2009 and 2010-2012 respectively. The similar confidence intervals observed in these two birth cohorts also suggest that the magnitude of the effect of the midday meals intervention on the height-for-age zscore is similar across the two cohorts.

The results indicate some interesting patterns with regards to the impact of the midday meals intervention. Particularly, among the older cohort of children (i.e. 2007-2009 and 2010-2012 birth-year cohorts) a strong positive treatment effect is seen on the height-for-age zscore of children while among children in the youngest cohort (i.e. 2013-2015 birth-year cohort) a particularly strong positive treatment effect is observed on the weight-for-age and BMI-for-age of children. This suggests that, as intended, the program has a positive influence on improving the height-for-age among children who have had a longer period of involvement, implying that the program is effective in improving long-term growth. The positive influence on improving weight and BMI would presumably, in time translate into improvements in height.

Figure 5: The relationship between weight-for-age zscore by birth-year cohort and access to the midday meals program

Figure 6: The relationship between BMI-for-age zscore by birth-year cohort and access to the midday meals program

Figure 7: The relationship between height-for-age zscore by birth-year cohort and access to the midday meals program

With regards to the validity of instruments used within the subsamples, the K-P, C-D and S-H tests report the instruments to be valid in all fitted models, with the exception of three models (underidentification in *zwei* model (2007-2009) and overidentified in *zbmi* model (2010-2012) and *zhei* model (2013-2015)). However, the treatment effects are not statistically significant for both the IV and GLS models in all three instances noted. Model results for IV-RE models by birth-year cohorts is presented in Table 6.

Insert Table 6 here

Treatment Effects on Underweight, Wasting and Stunting

Logistic regression models were fitted to model the relationship between access to the midday meals intervention and the likelihood of being underweight, wasted and stunted of children. Figure 8 presents the estimated coefficients and Table 7 presents the estimated odds ratios and fractional

odds of being underweight, wasted and stunted based on access to the intervention. The estimated coefficients are all negative, indicating that access to the intervention reduce the likelihood of being underweight, wasted and stunted. However, statistically significant effects are detected only on the likelihood of being underweight and wasted. According to the fractional odds indicated in Table 7, for a given child, the odds of being underweight and wasted decreased by 0.45 (45%) and 0.47 (47%) respectively, if the child had access to the midday meals intervention. The results clearly indicate the effectiveness of the midday meals intervention in reducing the prevalence of underweight and wasting among children within tea plantations. No statistically significant effects are observed on the prevalence of stunting.

Figure 8: The relationship between the likelihood of being underweight, wasted and stunted and access to the midday meals program (coef)

Table 7: Estimated coefficients, odds-ratio and fractional odds for the treatment effect in underweight, wasting and stunting models

Model	Underweight	Wasting	Stunting
Coef (Std Dev)	-0.604** (0.152)	-0.641** (0.191)	-0.219 (0.176)
95% CI	(-0.901, -0.307)	(-1.016, -0.267)	(-0.565, 0.127)
Odds-Ratio (Std Dev)	0.547** (0.083)	0.527** (0.101)	0.803 (0.142)
95% CI	(0.406, 0.736)	(0.362, 0.766)	(0.568, 1.135)
Fractional Odds (%)	-0.453** (45.3%)	-0.473** (-47.3%)	-0.197 (-19.7%)
95% CI	(-0.594, -0.264)	(-0.638, -0.234)	(-0.432, 0.135)
N	17214	7470	10309
Robust standard errors in parenthesis, **p<0.01, *p<0.05, + p<0.1			

Model results for logistic random effects *underweight*, *wasting* and *stunting* models are presented in Table 8.

Insert Table 8 here

Robustness

As noted earlier, non-random attrition poses a significant challenge given the time window in which anthropometric measures were collected. Following the methods commonly used for accounting for attrition [26,28], we re-estimate equation (1) using attrition weights as a robustness test. The inclusion of attrition weights did not impact the statistical significance or direction of the treatment variable in the *zwei* and *zhei* models. The magnitude of the estimated effects is very similar but slightly lower, in line with expectations. Therefore, attrition is not considered to significantly alter results.

Other robustness checks included using different estimation methods (i.e. GLS-RE) and subsamples (by gender, birthweight and birth-year), results of which were previously discussed.

Discussion

The primary intention of this paper was to identify whether access to the midday meals program had a positive impact on the growth of pre-school children living within tea plantation communities.

Overall results clearly indicate a strong positive impact of access to the midday meals intervention on the growth of children at different levels. Preliminary analysis revealed that the treatment group displayed relatively poor anthropometric measures compared to the control group in the 0-6 month age category. However, growth was observed to clearly improve within the treatment group, in the post-treatment period (7-60 months age group). Figures 9-11 present the information provided in Table 2 in a different form. The figures in order, present the percentage of underweight, wasted and stunted children in the overall, treatment and control samples in the 0-6 month and 7-60 month age groups. A few patterns clearly emerge. The proportion of underweight has clearly increased in the overall, treatment and control samples in the 7-60 month age category compared to the 0-6 month age category, whilst the proportion of wasting is seen to markedly decrease across all three groups, in the 7-60 month age category. In Figure 9, the proportion of underweight children in the control group shows a large increase from the 0-6 month to 7-60 month age categories, whilst the increase is far smaller in the treatment group. Similarly, in Figure 10, the treatment group shows a larger decline in the proportion of wasting from the baseline to the 7-60 month age group, going from being 5 percentage points higher than the control group at baseline to one percentage point lower after the treatment. With regards to the proportion of stunting in Figure 11, a general increase in the proportion is observed from the baseline to the 7-60 month age category, across all three groups. However, the increase is clearly higher within the control group (43% to 59%, compared to 43% to 48% for the treatment group). These results suggest two clear points. Firstly, results clearly indicate a general deterioration in growth over age, that is observed for children living within the tea plantation community, compared to the WHO reference population. This is in line with similar patterns observed in other studies where the growth of children in developing countries is observed

to be closer to the reference population, at birth but falls further behind the reference population with age [27]. The results also clearly suggest that the decline in growth with age is reduced within the treatment group compared to the control group. This suggests the beneficial impact of the midday meals program as a nutritional safety net, a finding endorsed by estimated models.

Figure 9: Percentage underweight within the 0-6 month and 7-60 month age category within the overall, treatment and control samples

Figure 10: Percentage wasting within the 0-6 month and 7-60 month age category within the overall, treatment and control samples

Figure 11: Percentage stunting within the 0-6 month and 7-60 month age category within the overall, treatment and control samples

Both the IV and GLS models on the overall sample suggest that access to the midday meals program results in significantly improved standardized weight-for-age and height-for-age of children. Results highlight two important aspects. Firstly, the significant impact of access to the program on the long-term growth of children (as reflected by height-for-age) suggests that midday meals programs of this nature can be used as effective tools for improving child growth and more importantly helping nutritionally deprived children to catch up in growth (as indicated by the pre- and post-treatment descriptive analysis). Secondly, the results also signal that children within treatment plantations fare significantly better in terms of growth compared to children from the control plantation, irrespective of actual participation in the program. Hence, having access to a program such as the midday meals program, with low entry barriers, can act as a nutritional safety net for pre-school aged children. The logistic model results indicate that access to the midday meals program significantly reduces the prevalence of underweight and wasting among children within tea plantations.

It is useful to examine the factors that may drive these positive effects. As noted in the methodology, the estate midwives and child development officers at the CDCs were interviewed as part of the study to collect qualitative insights into possible mechanisms through which these positive effects could manifest. Midwife interviews revealed significant issues related to access to protein-rich food, intake of imbalanced meals and diet preferences within the plantation communities, highlighting these factors as potential drivers of child malnutrition within tea plantations. Inappropriate feeding practices and lack of dietary diversity have also been highlighted as significant issues by prior research into the nutrition status of plantation communities in Sri Lanka [29,30]. Given that the midday meals intervention was designed in consultation with nutrition experts, specifically targeting nutritional needs of children below the age of five years, the intervention would be an effective mechanism in bridging these nutritional gaps.

Issues surrounding pregnancy patterns and antenatal care were also highlighted by midwives, particularly noting that plantation women tend to have 3-4 close pregnancies, resulting in a lack of care afforded to older children in most cases. This trend can also lead to significant challenges with food security at the household level. The midday meals intervention would be able to effectively address this issue, through the provision of balanced midday meals to children. Multiple children from the same family being part of the midday meals program will also promote equitable access to nutrients among children belonging to the same family, which would promote growth.

Alcohol abuse was also noted as a clear issue by midwives, a concern that has also been noted by several other studies [12,30,31]. This highlights the potential usefulness of programs such as the midday meals intervention in the setting of tea plantations in Sri Lanka, over more traditional interventions such as cash transfer programs, which give discretion to parents about how the cash is spent with possible adverse outcomes for children.

When considering the impact of the intervention within particular cohorts, the greater benefits of program access for girls compared to boys is an interesting observation. Whilst this does not particularly signal inequity in program effects, since access to the intervention also shows statistically significant positive impacts (though smaller in magnitude) on the growth of boys, it is interesting to explore the result further. A breakdown of actual program take-up by gender showed similar take-up by girls and boys, which indicates that the observed differential effects are not driven by gender differences in treatment adoption or intensity. Given that the labour structure in tea plantations is predominantly female driven, gender differentials in treatment effects, therefore, could reflect certain systemic and structural biases which favour girls more than boys, as girls are seen in the light of a future labour force. This pattern warrants further exploration through future studies.

Access to the midday meals intervention is also seen to disproportionately favour children born with normal or high birthweights compared to children born with low birthweight. Whilst a statistically significant positive treatment effect on the weight-for-age of low birthweight children was observed in the GLS-RE models, the magnitude of the effect was much lower for low birthweight children compared to the treatment effect on children with normal/high birthweight. No statistically significant treatment effects were observed on the height-for-age of children in the low birthweight cohort. This may imply that the intervention falls short of benefiting the long-run growth of more vulnerable cohorts of children, who may require more targeted interventions. From a program design perspective, this is critical and warrants further exploration to identify why program benefits appeared to be weaker among the children who need it the most. It is interesting to note that a breakdown of actual program take-up in the two treatment plantations showed that only 35% of children born with low birthweight participated in the midday meals program in one of the treatment plantations, whilst a relatively higher proportion of low birthweight children (67%) were program participants in the other treatment plantation. This could be the main reason driving the

non-significant treatment effects among low birthweight children and indicates a clear need for promoting and popularizing the midday meals program among families with low birthweight children. In addition, it is likely that further support may be required for these children (e.g. nutrition education, regular monitoring, and supplementary nutrition), in order to correct for growth deficits.

With regards to the scalability of midday meals interventions within similar settings, the wide network of established child development centres (CDCs) within tea plantations in Sri Lanka can be identified as a practical and feasible setting through which similar midday meals programs can be implemented across other tea plantations. Previous studies have highlighted the impact of CDCs and the crucial role of child development officers (CDOs) in facilitating interactions between children, their mothers and public health midwives as well as their potential to act as mediators in child-centric development programs [29]. This makes CDCs and CDOs the ideal setting for a widescale implementation of a nutrition intervention such as a midday meals program. Interviews with CDOs also revealed common practices such as maintaining home-gardens within CDCs as well as plantation households. This would be a further value addition to the midday meals program and would also encourage community participation through the provision of fresh home-grown produce for preparation of the midday meals at CDCs. Together, these factors point towards the high feasibility and scalability of such programs within the target population.

Conclusion

The analysis clearly suggests that midday meals can be used as an effective early childhood nutrition intervention to promote child growth among vulnerable population groups such as the tea plantation community in Sri Lanka. Midday meals programs similar to the one studied are scalable given the established system of child development centres within tea plantations and there is scope for value addition through home gardens maintained within most plantations. However, continuous

monitoring of the program is required to improve its reach and effectiveness among particularly vulnerable children within these communities.

Additional file

Additional file 1: Public Health Midwife Questionnaire, CDO Questionnaire and Household Quality Checklist used in the study (PDF 233 kb).

Abbreviations

BMI: Body Mass Index; CDC: Child development centre; CDO: Child development officer; CI: Confidence interval; DHS: Demographic and health survey; GLS-RE: Generalized least squares random-effects; HH: Household; IV-RE: Instrument variable random-effects; MUDREC: Monash University Human Research Ethics Committee; OR: Odds ratio; RPC: Regional plantation company; WHO: World health organization; ZBMI: Standardized Body mass index-for-age; ZHEI: Standardized Height-for-age; ZWEI: Standardized Weight-for-age; ZWFH: Standardized Weight-for-Height/Length

Declarations

Ethics Approval and Consent to Participate

Ethics approval for the study was obtained from the Monash University Human Research Ethics Committee (Reference No.: CF15/1502-2015000740). Written informed consent was obtained by the midwives and child development officers interviewed during the study. Parental consent was not required by the Monash Ethics Committee as no children were directly interviewed or observed during the study. The study relies on secondary data routinely collected and maintained by midwives and child development officers and was provided in a non-identifiable format following privacy protocols.

Consent for Publication

Not applicable for this study.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

BAI and UDSP conceived and designed the natural experiment and survey. UDSP performed the field survey and collected all necessary data. BAI and UDSP were both involved in data interpretation and statistical analysis. UDSP wrote the first draft of the manuscript. BAI critically revised the manuscript for intellectual content. UDSP and BAI are guarantors of the paper. Both authors have read and approved the manuscript.

Competing interests

The authors declare that they have no competing interests.

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Table 3: IV and GLS regression main-effects model results

		<i>IV and GLS – Random Effects Regression</i>					
		<i>zwei</i>		<i>zhei</i>		<i>zbmi</i>	
		IV	GLS	IV	GLS	IV	GLS
Treatment var							
<i>Trt</i>		0.031** (0.006)	0.078** (0.012)	0.047** (0.012)	0.053** (0.014)	0.0004 (0.018)	-0.018 (0.019)
Instrumented var							
<i>zwei_{i,t-1}/ zhei_{i,t-1}/</i>		1.012** (0.025)	0.731** (0.009)	0.913** (0.008)	0.904** (0.011)	0.847** (0.017)	0.839** (0.01)
<i>zbmi_{i,t-1}</i>							
Child-level							
<i>Age</i>		0.006** (0.002)	-0.005** (0.001)	0.007** (0.002)	0.007** (0.002)	-0.01** (0.003)	-0.01** (0.003)
<i>Age_sq</i>		-0.0001** (0.00002)	0.0001** (0.00002)	-0.0001** (0.00003)	-0.0001* (0.00003)	0.0001* (0.00004)	0.0001* (0.00004)
<i>Gender</i>	Male	0.016** (0.004)	-0.012 (0.011)	-0.004 (0.01)	-0.005 (0.011)	0.011 (0.014)	0.009 (0.014)
<i>firstzweight</i>		-0.043* (0.017)	0.14** (0.009)	0.037** (0.006)	0.038** (0.006)	0.057** (0.01)	0.053** (0.009)
<i>firstzheight</i>					0.006 (0.01)		0.002 (0.009)
<i>mwv</i>		0.07** (0.019)	0.077* (0.033)	0.074* (0.036)	0.093* (0.043)	-0.121* (0.06)	-0.104+ (0.062)
<i>zbirthweight</i>			0.02** (0.005)	-0.004 (0.005)	-0.004 (0.005)		0.019* (0.008)
<i>Ethnicity</i>	Sinhalese	0.004 (0.007)	0.012 (0.022)	0.019 (0.018)	0.019 (0.019)	-0.074** (0.025)	-0.069** (0.025)

Table 3 ctd.

		<i>IV and GLS – Random Effects Regression</i>					
		<i>zwei</i>		<i>zhei</i>		<i>zbmi</i>	
		IV	GLS	IV	GLS	IV	GLS
CDC-level							
<i>CDC_category</i>	New	0.004 (0.006)	-0.002 (0.017)	-0.002 (0.015)	-0.004 (0.016)	-0.038+ (0.022)	-0.05* (0.023)
	Upgraded	0.004 (0.006)	0.0005 (0.015)	0.008 (0.016)	0.011 (0.017)	-0.021 (0.02)	-0.027 (0.021)
<i>_cons</i>		-0.111 (0.091)	-0.348** (0.096)	-0.577** (0.081)	-0.626** (0.089)	0.418** (0.1)	0.409** (0.103)
<i>N</i>		17214	17214	10309	10309	7780	7780
σ_u		0.035	0.094	0.108	0.153	0	0.092
σ_e		0.309	0.306	0.237	0.224	0.700	0.490
ρ		0.012	0.086	0.171	0.318	0	0.034
Underidentification							
<i>Kleibergen-Paap LM Stat</i>		23.80**		123.44**		81.11**	
Weak-instrument							
<i>Cragg-Donald Wald F statistic</i>		82.13		1262.49		429.00	
Overidentification							
<i>Sargan-Hansen test</i>		0.613		0.138		7.838*	

Robust standard errors in parenthesis, **p<0.01, *p<0.05, + p<0.1

K-P LM test [Null: matrix of reduced form coefficients has rank=K1-1], C-D Wald F Test [Null: Equation is weakly identified], S-H Test [Null: Overidentification restriction is satisfied]. Birth-year fixed effects excluded from table.

Table 4: IV regression model results- by Gender

		IV– Random Effects Regression					
		<i>zwei</i>	<i>Female zhei</i>	<i>zbmi</i>	<i>zwei</i>	<i>Male zhei</i>	<i>zbmi</i>
Treatment var							
<i>Trt</i>		0.033** (0.012)	0.052** (0.016)	0.016 (0.024)	0.033** (0.008)	0.039* (0.018)	-0.011 (0.026)
Instrumented var							
<i>zwei_{i,t-1}/ zhei_{i,t-1}/ zbmi_{i,t-1}</i>		1.006** (0.043)	0.908** (0.016)	0.828** (0.029)	1.001** (0.037)	0.917** (0.009)	0.868** (0.018)
Child-level							
<i>Age</i>		0.004+ (0.003)	0.006* (0.003)	-0.013** (0.004)	0.007** (0.002)	0.008** (0.003)	-0.008+ (0.004)
<i>Age_sq</i>		-0.00004 (0.00003)	-0.0001 (0.00004)	0.0001* (0.00005)	-0.0001** (0.00003)	-0.0001** (0.00004)	0.0001 (0.0001)
<i>firstzweight</i>		-0.039 (0.03)	0.039** (0.012)	0.055** (0.015)	-0.04 (0.025)	0.037** (0.007)	0.052** (0.014)
<i>mwv</i>		0.095** (0.025)	0.071+ (0.043)	-0.089 (0.075)	0.052+ (0.031)	0.073 (0.054)	-0.123 (0.089)
<i>zbirthweight</i>			-0.004 (0.008)			-0.005 (0.006)	
<i>Ethnicity</i>	Sinhalese	-0.004 (0.011)	0.044+ (0.025)	-0.128** (0.034)	0.02 (0.012)	-0.008 (0.021)	-0.005 (0.039)

Table 4 ctd.

		IV– Random Effects Regression					
		Female			Male		
		<i>zwei</i>	<i>zhei</i>	<i>zbmi</i>	<i>zwei</i>	<i>zhei</i>	<i>zbmi</i>
CDC-level							
<i>CDC_category</i>	<i>New</i>	0.008 (0.01)	0.008 (0.02)	-0.036 (0.031)	-0.001 (0.009)	0.002 (0.021)	-0.036 (0.03)
	<i>Upgraded</i>	0.005 (0.011)	0.014 (0.02)	-0.03 (0.027)	0.0002 (0.008)	0.008 (0.022)	-0.016 (0.028)
<i>_cons</i>		-0.177+ (0.092)	-0.606** (0.053)	0.126 (0.091)	-0.096 (0.167)	-0.539** (0.1)	0.435** (0.135)
<i>N</i>		8567	5285	3948	8647	5024	3832
σ_u		0.039	0.090	0	0.060	0.109	0
σ_e		0.299	0.335	1.187	0.350	0.243	1.029
ρ		0.017	0.068	0	0.029	0.167	0
Underidentification test							
<i>Kleibergen-Paap LM Stat</i>		9.28**	68.84**	44.78**	15.85**	65.35**	44.61**
Weak instrument test							
<i>Cragg-Donald Wald F statistic</i>		31.95	689.29	170.36	37.61	785.13	278.65
Overidentification test							
<i>Sargan-Hansen score</i>		0.457	0.666	7.276*	0.132	0.019	4.564

Robust standard errors in parenthesis, **p<0.01, *p<0.05, + p<0.1.

K-P LM test [Null: matrix of reduced form coefficients has rank=K1-1], C-D Wald F Test [Null: Equation is weakly identified], S-H Test [Null: Overidentification restriction is satisfied]. Birth-year fixed effects excluded from table.

Table 5: IV regression model results- by Birthweight

		IV– Random Effects Regression					
		Low BW			Normal/High BW		
		<i>zwei</i>	<i>zhei</i>	<i>zbmi</i>	<i>zwei</i>	<i>zhei</i>	<i>Zbmi</i>
Treatment var							
<i>Trt</i>		0.009 (0.075)	0.024+ (0.014)	0.004 (0.02)	0.036** (0.007)	0.078** (0.023)	-0.047 (0.037)
Instrumented var							
<i>zwei_{i,t-1}/ zhei_{i,t-1}/ zbmi_{i,t-1}</i>		1.065** (0.352)	0.92** (0.012)	0.861** (0.023)	1.011** (0.023)	0.906** (0.011)	0.824** (0.024)
Child-level							
<i>Age</i>		0.001 (0.01)	0.004 (0.004)	-0.009* (0.004)	0.009** (0.002)	0.008** (0.003)	-0.01* (0.004)
<i>Age_sq</i>		0.00001 (0.0001)	-0.00004 (0.0001)	0.0001 (0.0001)	-0.0001** (0.00002)	-0.0001** (0.00004)	0.0001 (0.0001)
<i>Gender</i>	Male	0.022 (0.03)	-0.005 (0.014)	0.004 (0.018)	0.012* (0.006)	-0.007 (0.015)	0.013 (0.021)
<i>firstzweight</i>		-0.068 (0.249)	0.042** (0.011)	0.048** (0.014)	-0.052** (0.014)	0.03** (0.008)	0.051** (0.015)
<i>mwv</i>		0.047+ (0.027)	0.112* (0.049)	-0.173* (0.078)	0.093** (0.026)	0.048 (0.054)	-0.045 (0.093)
<i>zbirthweight</i>			0.003 (0.01)			0.006 (0.012)	
<i>Ethnicity</i>	Sinhalese	0.003 (0.053)	0.024 (0.03)	-0.105** (0.038)	0.01 (0.01)	0.018 (0.021)	-0.042 (0.035)

Table 5 ctd.

		IV– Random Effects Regression					
		Low BW			Normal/High BW		
		<i>zwei</i>	<i>zhei</i>	<i>zbmi</i>	<i>Zwei</i>	<i>zhei</i>	<i>zbmi</i>
CDC-level							
<i>CDC_category</i>	<i>New</i>	0.005 (0.048)	0.019 (0.019)	-0.056* (0.026)	-0.014 (0.009)	-0.038 (0.026)	-0.027 (0.037)
	<i>Upgraded</i>	-0.001 (0.051)	0.005 (0.019)	-0.023 (0.025)	-0.008 (0.008)	-0.0002 (0.027)	-0.013 (0.036)
<i>_cons</i>		0.053 (0.662)	-0.434** (0.131)	0.128 (0.14)	-0.19* (0.091)	-0.597** (0.101)	0.415** (0.129)
<i>N</i>		7336	4847	3740	9878	5462	4040
σ_u		0	0.102	0	0	0.114	0.081
σ_e		15.420	0.227	1.034	0.430	0.246	0.611
ρ		0	0.168	0	0	0.176	0.017
Underidentification test							
<i>Kleibergen-Paap LM Stat</i>		0.14	64.62**	37.67**	25.88**	56.42**	
Weak instrument test							
<i>Cragg-Donald Wald F statistic</i>		0.44	687.65	238.80	106.09	548.89	
Overidentification test							
<i>Sargan-Hansen score</i>		0.668	0.080	0.312	4.136*	0.059	

Robust standard errors in parenthesis, **p<0.01, *p<0.05, + p<0.1.

K-P LM test [Null: matrix of reduced form coefficients has rank=K1-1], C-D Wald F Test [Null: Equation is weakly identified], S-H Test [Null: Overidentification restriction is satisfied]. Birth-year fixed effects excluded from table.

Table 6: IV regression model results- by Birth-Year Cohort

		IV– Random Effects Regression								
		2007-2009			2010-2012			2013-2015		
		<i>zwei</i>	<i>zhei</i>	<i>zbmi</i>	<i>zwei</i>	<i>zhei</i>	<i>zbmi</i>	<i>zwei</i>	<i>zhei</i>	<i>zbmi</i>
Treatment var										
<i>Trt</i>		0.003 (0.02)	0.046* (0.021)	-0.023 (0.033)	0.008 (0.006)	0.044** (0.014)	-0.011 (0.021)	0.073** (0.018)	-0.008 (0.051)	0.17** (0.053)
Instrumented var										
<i>zwei_{i,t-1}/ zhei_{i,t-1}/</i>		1.076** (0.367)	0.937** (0.017)	0.883** (0.023)	1.031** (0.029)	0.917** (0.01)	0.852** (0.021)	1.029** (0.022)	0.873** (0.023)	0.788** (0.055)
Child-level										
<i>Age</i>		0.002 (0.008)	0.004 (0.009)	0.001 (0.016)	0.006** (0.002)	0.005* (0.002)	-0.01** (0.004)	0.03** (0.007)	0.039 (0.022)	-0.015 (0.026)
<i>Age_sq</i>		-0.00002 (0.0001)	-0.00004 (0.0001)	-0.00003 (0.0002)	-0.0001* (0.00002)	-0.0001+ (0.00003)	0.0001* (0.0001)	-0.001** (0.0002)	-0.001 (0.001)	-0.0002 (0.001)
<i>Gender</i>		-0.001 (0.019)	0.007 (0.015)	0.003 (0.022)	0.022** (0.004)	0.001 (0.011)	0.008 (0.016)	0.006 (0.011)	-0.027 (0.047)	-0.034 (0.053)
<i>firstzweight</i>		-0.075 (0.285)	0.049** (0.014)	0.031* (0.014)	-0.046* (0.019)	0.032** (0.008)	0.061** (0.013)	-0.092** (0.017)	0.012 (0.024)	0.05 (0.033)
<i>mww</i>		0.006 (0.068)	0.083* (0.038)	-0.038 (0.107)	0.058** (0.018)	0.097* (0.039)	-0.152* (0.07)	0.181** (0.07)	-0.025 (0.237)	-0.259 (0.263)
<i>zbirthweight</i>			-0.014+ (0.007)			-0.006 (0.006)		0.041 (0.043)		
<i>Ethnicity</i>	Sinhalese	0.003 (0.076)	-0.017 (0.018)	-0.05 (0.032)	-0.001 (0.005)	0.037 (0.024)	-0.077* (0.031)	0.047+ (0.026)	-0.038 (0.068)	0.225* (0.105)

Table 6 ctd.

		IV– Random Effects Regression								
		2007-2009			2010-2012			2013-2015		
		<i>zwei</i>	<i>zhei</i>	<i>zbmi</i>	<i>zwei</i>	<i>zhei</i>	<i>zbmi</i>	<i>zwei</i>	<i>zhei</i>	<i>zbmi</i>
CDC-level										
<i>CDC_category</i>	<i>New</i>	0.01 (0.013)	-0.005 (0.032)	-0.017 (0.05)	0.009+ (0.006)	0.013 (0.016)	-0.048+ (0.025)	-0.024+ (0.014)	-0.079* (0.054)	-0.029 (0.077)
	<i>Upgraded</i>	0.012 (0.016)	-0.032 (0.033)	0.026 (0.051)	0.007 (0.005)	0.017 (0.015)	-0.033 (0.022)	-0.025* (0.012)	0.006 (0.059)	-0.003 (0.066)
<i>_cons</i>		0.068 (0.899)	-0.283 (0.227)	-0.098 (0.404)	-0.142** (0.038)	-0.389** (0.056)	0.245* (0.101)	-0.334** (0.113)	-0.727** (0.244)	0.503 (0.307)
<i>N</i>		2468	1878	1282	11192	7562	5835	3554	869	663
σ_u		0	0	0	0	0.098	0	0	0.142	0
σ_e		1.438	2.180	2.508	0.401	0.274	0.820	0.756	0.389	0.830
ρ		0	0	0	0	0.113	0	0	0.118	0
Underidentification test										
<i>Kleibergen-Paap LM Stat</i>		0.27	31.08**	25.61**	8.73*	91.40**	50.59**	20.72**	17.80**	18.51**
Weak instrument test										
<i>Cragg-Donald Wald F stat</i>		0.72	458.22	229.10	43.68	858.58	250.91	114.15	360.20	46.92
Overidentification test										
<i>Sargan-Hansen score</i>		2.036	0.081	0.409	0.040	1.227	10.091**	1.194	4.262*	3.397

Robust standard errors in parenthesis, **p<0.01, *p<0.05, +p<0.1.

K-P LM test [Null: matrix of reduced form coefficients has rank=K1-1], C-D Wald F Test [Null: Equation is weakly identified], S-H Test [Null: Overidentification restriction is satisfied]. Birth-year fixed effects excluded from table.

Table 8: Logit RE regression – Underweight, Wasting and Stunting

		<i>Logit– Random Effects Regression</i>					
		<i>Underweight</i>		<i>Wasting</i>		<i>Stunting</i>	
		<i>Coef</i>	<i>Odds R</i>	<i>Coef</i>	<i>Odds R</i>	<i>Coef</i>	<i>Odds R</i>
Treatment var							
<i>Trt</i>		-0.604** (0.152)	0.547** (0.083)	-0.642** (0.191)	0.526** (0.101)	-0.219 (0.176)	0.803 (0.142)
Instrumented var							
<i>zwei_{i,t-1}/ zbm_{i,t-1}/ zhei_{i,t-1}</i>		-3.703** (0.162)	0.025** (0.004)	-2.537** (0.123)	0.079** (0.01)	-8.416** (0.607)	0.0002** (0.0001)
Child-level							
<i>Age</i>		0.039** (0.013)	1.04** (0.014)	-0.032 (0.028)	0.969 (0.027)	-0.045 (0.03)	0.956 (0.029)
<i>Age_sq</i>		-0.001* (0.0002)	0.999* (0.0002)	0.0002 (0.0004)	1 (0.0004)	0.001 (0.0004)	1.001 (0.0004)
<i>Gender</i>	Male	0.086 (0.121)	1.09 (0.132)	0.881** (0.138)	2.412** (0.332)	-0.274+ (0.148)	0.76+ (0.112)
<i>firstzweight</i>		-1.029** (0.12)	0.357** (0.043)	-0.802** (0.104)	0.449** (0.046)	-0.249** (0.093)	0.78** (0.073)
<i>fristzheight</i>				-0.052 (0.083)	0.95 (0.079)	0.298* (0.133)	1.347* (0.18)
<i>mwv</i>		-1.029** (0.356)	0.358** (0.127)	-0.563 (0.418)	0.569 (0.238)	-0.313 (0.456)	0.731 (0.333)
<i>zbirthweight</i>		-0.215** (0.07)	0.806** (0.056)	-0.205* (0.085)	0.815* (0.069)	0.017 (0.095)	1.017 (0.097)
<i>Ethnicity</i>	Sinhalese	-0.073 (0.22)	0.93 (0.204)	0.113 (0.217)	1.12 (0.243)	-0.269 (0.275)	0.764 (0.21)

Table 8 ctd.

			Logit– Random Effects Regression					
			Underweight		Wasting		Stunting	
			Coef	Odds R	Coef	Odds R	Coef	Odds R
CDC-level								
CDC_category	New		0.122 (0.174)	1.13 (0.196)	0.319 (0.205)	1.376 (0.282)	0.356 (0.245)	1.427 (0.35)
	Upgraded		-0.023 (0.171)	0.978 (0.167)	-0.178 (0.22)	0.837 (0.184)	0.355 (0.233)	1.426 (0.332)
_cons			-9.758** (0.843)	0.0001** (0.0001)	-4.648** (0.682)	0.01** (0.007)	-13.601** (1.356)	0** (0)
N			17214		7470		10309	
ln σ_u			0.490		-0.615		-0.308	
σ_u			1.278		0.735		0.857	
ρ			0.332		0.141		0.183	
Robust standard errors in parenthesis, **p<0.01, *p<0.05, + p<0.1. Birth-year fixed effects excluded from table.								

Figures

Figure 1

Histogram of weight-for-age zscores in the 0-6 month age category in treatment and control groups

Figure 2

The relationship between weight-for-age zscore and access to the midday meals program

Figure 3

The relationship between height-for-age zscore and access to the midday meals program

Figure 4

The relationship between BMI-for-age zscore and access to the midday meals program

Figure 5

The relationship between weight-for-age zscore by birth-year cohort and access to the midday meals program

Figure 6

The relationship between BMI-for-age zscore by birth-year cohort and access to the midday meals program

Figure 7

The relationship between height-for-age zscore by birth-year cohort and access to the midday meals program

Figure 8

The relationship between the likelihood of being underweight, wasted and stunted and access to the midday meals program (coef)

Figure 9

Percentage underweight within the 0-6 month and 7-60 month age category within the overall, treatment and control samples

Figure 10

Percentage wasting within the 0-6 month and 7-60 month age category within the overall, treatment and control samples

Figure 11

Percentage stunting within the 0-6 month and 7-60 month age category within the overall, treatment and control samples

Supplementary Files

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