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The Impact of Prenatal Exposure to Fasting on Child Health Outcomes

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Preface

The Centre for Research in Economics and Business (CREB) was established in 2007 to conduct policy-oriented research with a rigorous academic perspective on key development issues facing Pakistan. In addition, CREB (i) facilitates and coordinates research by faculty at the Lahore School of Economics, (ii) hosts visiting international scholars undertaking research on Pakistan, and (iii) administers the Lahore School's postgraduate program leading to the MPhil and PhD degrees.

An important goal of CREB is to promote public debate on policy issues through conferences, seminars, and publications. In this connection, CREB organizes the Lahore School's Annual Conference on the Management of the Pakistan Economy, the proceedings of which are published in a special issue of the Lahore Journal of Economics.

The CREB Working Paper Series was initiated in 2008 to bring to a wider audience the research being carried out at the Centre. It is hoped that these papers will promote discussion on the subject and contribute to a better understanding of economic and business processes and development issues in Pakistan. Comments and feedback on these papers are welcome.

Abstract

Early-life factors play an important role in fetal development, according to Barker's (1990) 'womb-with-a-view' hypothesis. This study examines how prenatal exposure to fasting in the month of Ramadan has an impact on child health outcomes in terms of height-for-age and weight-for-age z-scores.

In the absence of actual reported fasting behaviors, we use the 'intent-to-treat' (ITT) approach, as applied in randomized control trials. This allows one to measure the unbiased impact of an intervention, even when there is imperfect compliance with random assignment into control and treatment groups. While the ITT approach does not require or assume that all women pregnant during Ramadan necessarily fast, it is critical for Ramadan to remain exogenous to the timing of pregnancy. In other words, we assume that women do not intentionally time their pregnancies to fall outside of Ramadan.

The ITT framework is used to compare the health outcomes of two groups of children under five in the Punjab – those whose period in utero coincided with the month of Ramadan (the treatment group) and those who were not exposed (the control group). This is done without using any information on maternal fasting behavior. In each case, the child's date of birth establishes whether the pregnancy overlapped with the month of Ramadan and this information is used to construct a set of gestational month-of-exposure variables. The data for this analysis is drawn from the Multiple Indicator Cluster Survey for 2008 and 2011, carried out by the (Punjab) Bureau of Statistics.

The study's results indicate that prenatal exposure to fasting during the first two trimesters has negative implications for children's height-for-age. In addition, children who were prenatally exposed to fasting in the second and third trimesters were, on average, thinner than nonexposed children. We find no evidence of selection bias arising from the decision to selectively time a pregnancy to avoid Ramadan – a major concern of our study.

The Impact of Prenatal Exposure to Fasting on Child Health Outcomes

1. Introduction

Early-life factors often have a long-lasting impact on individuals, either in the form of general health status or educational attainment later in life. Barker (1990) explains the importance of early-life factors through his famous 'womb-with-a-view' hypothesis – also referred to as 'fetal origins' – according to which nutritional deficiencies during fetal development can result in higher risks of coronary heart diseases, hypertension and diabetes later in life.

The literature focuses on the importance of investments in early childhood and how these increase human capital more effectively than those made after a child has begun formal schooling. Doyle et al. (2009) discuss the importance of early childhood interventions in terms of the 'antenatal investment hypothesis', according to which, early childhood interventions such as prenatal care yield greater benefits at lower costs compared to postnatal investments. Thus, early childhood inputs offer far greater social and economic returns.

Heckman and Masterov (2007) observe that children's early environment is a more productive means of enhancing human capital. Their rationale is that early childhood interventions increase the efficiency of schools through the enrolment of students whose better-developed cognitive abilities ensure that their productivity is already high. Educational attainment does not depend solely on investments in the education sector: rather, early childhood interventions play a significant role in determining later outcomes, whether in the form of health or education.

If children's early-life environment is critical to their mental and physical development, by extension one cannot ignore the impact of maternal behavior during pregnancy. As van Ewijk (2011) shows, maternal behavior during pregnancy in terms of diet and health can have long-lasting effects on fetal development. When mothers reduce their food intake, whether by skipping meals or fasting, this may have adverse implications for their children's future health. This is because the maternal diet programs the fetus such that any variations in diet become apparent in (the child's) later life. Barker's (1990) 'womb-with-a-view' hypothesis explains how this fetal programming might be altered. He suggests that nutritional deficiencies during pregnancy cause the fetus to channel resources toward the development of those organs that are required immediately (till reproductive age) rather than focusing on long-term development.

Several studies show that the risk of various diseases such as coronary heart disease, diabetes and hypertension may be rooted in the period before birth. Harding (2001) concludes that it is not maternal nutrition, but rather fetal nutrition that alters fetal growth and may be associated with the risk of disease in later life.[1] For a sample of Muslim boys aged 3–4, Karimi (2015) finds that Ramadan-induced prenatal malnutrition had left them 3.5–10.5 mm shorter than their non-exposed peers. Inadequate fetal nutrition not only increases the risk of disease, but also alter the fetus's overall programming, with a permanent impact on the individual's physical and mental development in terms of body mass index (BMI) and cognitive skills, respectively. Complications in later life related to physical and mental wellbeing and the risk of disease may, therefore, originate in the period before birth.

Accordingly, this study underlines how maternal nutritional intake during pregnancy can affect the physical health – in terms of height-for-age and weight-for-age – of children under five. A cross-sectional study by Mubeen et al. (2012) shows that 87.5 percent of women reported fasting during Ramadan. Of this proportion, 42.5 percent fasted daily and 23.8 percent fasted every other day, while the remaining fasted less frequently. In this context, we analyze how exposure to fasting by pregnant women in Punjab during Ramadan affects their children's health in terms of height-for-age and weight-for-age. The study uses pooled cross-sectional data from the Multiple Indicator Cluster Survey (MICS) for Punjab, conducted in 2008 and 2011, to determine health outcomes among children under five. Specifically, this entails establishing the link between exposure to Ramadan during pregnancy – among children whose period inside the womb overlapped with the month of Ramadan – and offspring anthropometry.

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[1] Harding (2001) describes fetal nutrition as the "net supply of metabolic substrates to the fetus." This includes the mother's nutritional intake, maternal metabolism, umbilical blood flow and placental transfers, among other things.

As Almond et al. (2014) point out, one cannot separate out the impact of fasting from that of other activities or behaviors associated with Ramadan. Thus, the results of this study will capture the overall impact of all such aspects, including changes in sleep and eating patterns, reductions in caloric intake and unhealthy eating habits (since meals after fasting often include large portions of fried foods).

2. Literature Review

Ramadan, the ninth month of the lunar calendar, is regarded as a month of fasting among Muslims. This is considered an obligatory religious practice for all Muslims, apart from those who are sick or travelling, children under 12 and breastfeeding mothers.[2] Pregnant women may postpone fasting during Ramadan if they feel it is likely to damage their own health or that of the fetus. Despite this latitude, many pregnant Muslim women tend to fast during Ramadan. According to a Pakistani study gauging perceptions and practices of fasting during pregnancy, 88 percent of women of a sample of 353 believed that fasting was mandatory during a healthy pregnancy; almost the same proportion reported fasting when pregnant (Mubeen et al. 2012).

The link between prenatal fasting and long-term health outcomes arises through various mechanisms. Medical studies use these biomedical channels to explain their findings. Almond et al. (2015) discuss some of the pathways through which prenatal fasting can affect cognitive skill development, an important channel being 'accelerated starvation' associated with long hours of fasting. Prentice et al. (1983) show that accelerated starvation can occur when pregnant women fast during Ramadan, triggering a sudden decline in blood glucose levels and an increase in ketones and fatty acids. According to Rizzo et al. (1991), increased ketone levels in pregnant women with diabetes can increase the risk of lower cognitive abilities. The 'predictive adaptive response' channel is also used to explain how the early environment encountered by the fetus can, due to nutritional deficiencies, permanently alter the programming of the body development system. Gluckman and Hanson (2005) show that, if the fetus suffers from nutritional deficiency, it uses the resources it has, to develop the organs needed up until reproductive age. This increases the chances of heart-related disease and diabetes later in life.

[2] The Muslim fast involves abstaining from food and water from sunrise to sunset during the month of Ramadan.

The literature in this area is divided between medical research and studies by social scientists, both of which can be categorized by methodology. Medical studies tend to use smaller samples generally comprising clinical patients, but cannot, in most cases, control for confounding factors – in particular, when the endogeneity of the decision to fast results in omitted variable bias. This endogeneity might arise because women experiencing pregnancy complications are less likely to fast, so that the non-fasting group includes subjects who are less healthy. If not controlled for, this can lead to a bias-toward-zero effect on the coefficient of the impact of fasting, since the outcomes for healthy fasting women are compared against a group of non-fasting – but less healthy – pregnancies. This makes the impact of fasting look less damaging than if the latter were compared to a group of equally healthy women who fasted. In contrast, many of the studies performed by social scientists analyze large demographic datasets to understand the relationship that may persist between fasting while pregnant and children's mental and anthropometric health. However, these too can fall prey to omitted variable bias.

Several medical studies analyze the long-term impact of fasting during pregnancy. One such historical cohort-based study by Shahgheibi et al. (2005) concludes that maternal fasting during the third trimester does not affect newborns' growth parameters. An Irani study by Ziaee et al. (2010) reveals that there is no significant difference between fasting and non-fasting pregnant women in terms of BMI during early stages of pregnancy or in terms of average mean height, weight and other facets of infants' anthropometric development. Nor is there a significant difference in pregnancy outcomes when pregnant women fast during a different trimester.

A survey of 13,351 newborns in Birmingham by Cross et al. (1990) reveals that exposure to fasting does not have a significant impact on the average birth weight of infants whose period of gestation overlapped with Ramadan. The authors observe an increase in the incidence of low birth weight among infants who were prenatally exposed to Ramadan during the second trimester, but find the change is not significant. Similarly, results from another cohort study conducted in Iran by Kavehmanesh and Abolghasemi (2004) suggest that prenatal exposure to fasting has no significant impact on neonatal birth weight.

While much of the medical literature suggests that fasting during pregnancy has no significant impact on neonatal outcomes, it is worth considering that, in addition to endogeneity problems, these studies rely on small samples that may not be large enough to detect statistically significant differences, nor do they consider longer-term effects after the perinatal period. In failing to control for factors such as the mother's age, education, BMI, smoking behavior and birth order, all of which could affect child health outcomes as well as the decision to fast during pregnancy, such studies suffer from a severe simultaneity problem. In other words, these omitted variables mean that the results could assume an upward or downward bias, depending on the relationship between the omitted variable and the dependent and independent variables.[3] As we discuss below, some omitted variables may lead to underestimates of the impact of fasting, and others to overestimates.

If an omitted variable is inversely related to the decision to fast but negatively correlated with child health outcomes, then the impact of fasting may be underestimated because the 'control group' of non-fasting mothers is likely to feature, on average, relatively unhealthy pregnancies to begin with – making it harder to detect the negative impact of fasting. This might happen, for example, if older mothers are less likely to fast (Petherick et al. 2014) because, at the same time, older mothers also tend to experience worse birth outcomes. Factors that are positively related to the decision to fast as well as to health outcomes will also lead to an underestimate of the impact of fasting because they make the 'treatment group' of fasting mothers more likely to experience relatively healthy pregnancies compared to those not fasting – again, making it more difficult to gauge the impact of fasting.

Other factors might work in the opposite direction. If the omitted variable is positively (negatively) correlated with fasting but negatively (positively) correlated with child health outcomes, then the impact of fasting may be overestimated. This could potentially be the case with birth order, parental consanguinity and maternal education. However, even if studies controlled for observable maternal characteristics associated with the decision to fast as well as with child health outcomes, unobserved factors such as pregnancy complications are likely to confound the analysis. Women experiencing complications are

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[3] Even if a study were to control for these observable demographics, unobservables would remain (such as pregnancy complications) that would continue to confound the estimates.

less likely to fast and to have poorer pregnancy outcomes as well, biasing studies against determining the impact of fasting.

One study, Petherick et al. (2014), is an advance over the previous medical literature and controls for the mother's age, BMI, education and ethnicity in a study of South Asian Muslim women in the UK. The authors find that these factors do have an impact on women's decision to fast. The study does not find a statistically significant association (at the normal significance levels) between the decision to fast and child health outcomes when controlling for these factors, although the sample is small at 300 women. However, a closer look at the results is revealing. Women who fasted most days were more than twice as likely to have a low-birth-weight baby, but with a p-value of 0.17, this result is shy of the 10 percent standard significance level. The standard error is large and a bigger sample may have provided stronger evidence. Interestingly, it is also the women who fasted most days that were less likely to experience a pre-term birth ($p = 0.16$) in comparison to women who did not fast.

Since there is no clear medical reason that fasting should prevent pre-term birth, we hypothesize that reverse causality drives this result. This provides some indirect support for our conjecture above, that women with more complex pregnancies are less likely to fast, making it more difficult to detect a negative impact of fasting if those who deliberately choose not to fast are less healthy from the outset. To counter such problems, social scientists have begun to develop a literature that addresses the shortcomings of the medical literature to analyze the extent to which fasting during pregnancy can influence offspring development from childhood up until adulthood.

Social scientists have implemented natural experiments to control for the self-selection of women out of fasting. Almond and Mazumder (2011) is among the first studies to address the problem arising in many medical studies that compare pregnant women fasting at a point in time to those who were not fasting, since the decision to fast is not exogenous. Their approach is to compare birth outcomes in cases where the month of Ramadan happened to coincide with pregnancy to those where it did not. This analysis is carried out for such cases over a period of many years, without using any information on actual fasting behavior. The authors use the 'intent-to-treat' (ITT) approach to randomize the selection of the treatment and control groups. This is to ensure that women did not time their pregnancies with regard to Ramadan, so that the timing of Ramadan relative to the period of pregnancy can be considered exogenous. This approach is used in clinical trials and in the randomized control trial/program evaluation literature because it allows one to measure the unbiased impact of an intervention, even when there is imperfect compliance with researchers' random assignment into control and treatment groups. The approach does not require or assume that all women who are pregnant during Ramadan are fasting. What is critical, however, is that Ramadan is exogenous to the timing of pregnancy; in other words, women do not intentionally time their pregnancies to fall outside of Ramadan.

A growing body of literature presents evidence of how maternal fasting can affect the overall physiological development of offspring. Several studies, including Agüero and Valdivia (2010), Hidrobo (2014), Alderman et al. (2006) and Almond (2006), identify various economic and environmental shocks – such as recession, war, drought and influenza outbreak – that can have long-lasting impacts on child health outcomes. In this context, fetal exposure to fasting during Ramadan can also be considered a 'shock' that may affect the individual later in life.

Van Ewijk et al. (2013) use data from the Indonesian Family Life Survey to determine the association between prenatal exposure to Ramadan and the growth parameters (BMI, height and weight) of offspring in adulthood. They also investigate whether exposure to Ramadan during different gestational periods has any effect on these growth parameters. The authors find that adults whose in utero period coincided with Ramadan were thinner than their peers (whose in utero period did not overlap with Ramadan). Moreover, adults who were conceived during Ramadan were reportedly shorter than those who were not. These findings suggest that adult Muslims exposed to Ramadan in utero have a slightly lower weight and height.

In a similar study using Demographic and Health Survey data for 35 developing countries, Karimi (2015) finds that Ramadan-induced prenatal malnutrition caused Muslim boys aged 3 and 4 years to be 3.5–10.5 mm shorter than those who were not exposed. Brainerd and Menon (2015) show that fetal exposure to Ramadan fasting in utero can lead to positive selection among Muslim male infants. Their results also suggest that Muslim infants have better height-for-age z-scores than Hindu infants, but due partly to the positive selection of male infants.

Using census data for the US, Iraq and Uganda, Almond and Mazumder (2011) find that exposure to Ramadan in the first month of gestation is associated with the negative selection of males in Uganda. Moreover, there is a strong association between in utero exposure to Ramadan and lower birth weight as well as the likelihood of mental disability in adulthood. Similar results in terms of prenatal exposure to Ramadan and general health among the next generation emerges in van Ewijk (2011). The author gauges children's general health, as rated by professional health workers on a nine-point scale, and finds that people who were prenatally exposed to Ramadan fasting were in poorer health than the reference group.

Chen (2014) uses an interesting example of a mild economic shock causing undernourishment in addition to Ramadan fasting: overspending on festivals in certain societies. He argues that this social norm could negatively affect the fetus because excessive spending on food and presents by a household in relation to a festival would imply it has less to spare for pregnant women's nutritional needs. Ramadan fasting might also affect the fetus through changes in maternal eating behavior (higher intake of oily or unhealthy food) and altered timings of nutritional intake, even if the caloric intake is the same.[4]

Prenatal exposure to fasting may not only affect an individual's anthropometric growth parameters, but it can also influence her/his mental development. Several studies analyze how fetal exposure to Ramadan affects the mental and learning abilities of children. Greve et al. (2015) examine the effect of fetal nutrition on academic performance in later life, based on the standardized test scores (in English, math and science) of Muslim students living in Denmark. The study uses fetal exposure to Ramadan as a natural experiment, with non-Muslims as the control group.[5] The authors suggest that fetal exposure to Ramadan has a negative impact on academic performance among Muslim students, with a pronounced effect on girls and children from a low socioeconomic background.

Almond et al. (2011) conduct a study on Pakistani and Bangladeshi children in the UK and cite similar results in terms of test scores. Examining the impact of fasting during pregnancy on academic

[4] While some people alter their sleep patterns by staying up later and sleeping during the day in Ramadan, others keep regular working or school hours. Even pregnant women are likely to keep regular hours if they have children to send to school and other household chores to perform.

[5] If non-Muslims differ on time-varying observables, they may prove to be a weak control group.

performance, they find that children (aged 7 years) who were exposed to Ramadan during early pregnancy have lower test scores by a margin of 0.5–0.8 standard deviations. These studies are important in understanding how lack of nutrition during pregnancy due to fasting can affect offspring in later years.

Almond and Mazumder (2008) identify several ITT-related issues in terms of separating out the seasonality factor from fasting during pregnancy, because studies such as Doblhammer and Vaupel (2001) and Buckles and Hungerman (2013) argue that the season of birth can have a long-term impact. The age at which one is assessed can also play an important role in determining health outcomes. To separate out the seasonality effect, some studies take advantage of the gradual movement of Ramadan as it follows the lunar calendar, starting 11 days earlier every year. With a larger dataset on birth cohorts, the seasonality factor can be separated out by including month dummies as seasonal controls.

Almond et al. (2015) use a different technique applied to fewer birth cohorts and rely on the difference-in-difference approach to separate out seasonal effects by subtracting the effect on non-Muslims that might arise from seasonal variations from the effect on Muslims. To identify the treatment and control groups, the authors assume that the pregnancy was not planned in such a way as to avoid overlapping with Ramadan. This identification strategy assumes that there is no systematic selection of the timing of conception vis-à-vis the timing of Ramadan. This is done following Almond and Mazumder (2011) and van Ewijk (2011), both of which find no such selection bias based on a comparison of mean values for exposed and nonexposed individuals along dimensions such as parental education and health, household income and maternal smoking behavior.

In a study on in Bangladesh, however, Ahsan (2015) points to a selection bias in pregnancy timing relative to Ramadan when allowing for time-varying factors such as the availability of family planning.[6] This makes it essential to analyze, as a robustness check, whether any selection bias exists by gauging whether the sampled women timed their pregnancies so as not to overlap with Ramadan.

[6] Ahsan (2015) finds that women who were exposed to family planning were less likely to give birth eight to nine months after Ramadan, whereas better-educated mothers were less likely to time their pregnancies relative to Ramadan.

3. Methodology

This study aims to analyze the impact of fasting during pregnancy by women on child health outcomes such as weight and height for age among children under 5 years of age. In examining how exposure to fasting during Ramadan affects child health outcomes, we attempt to quantify the magnitude of this impact during different stages of pregnancy.

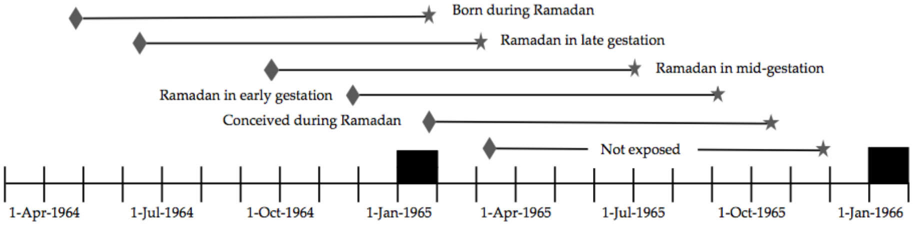
3.1. Month-of-Fasting (Ramadan) Exposure Measures

To understand the association between prenatal exposure to the month of fasting (Ramadan) and child health outcomes, we develop categories of prenatal exposure to fasting in Ramadan based on date of birth – as done by various studies, including van Ewijk (2011), van Ewijk et al. (2013) and Almond et al. (2015). For our analysis, the Ramadan exposure variable is generated based on the dates of birth of children aged 0–5 years. Children are considered prenatally exposed to Ramadan if any of the 266 days prior to their date of birth overlapped with the month of Ramadan (the treatment group). Here, we assume an average pregnancy period of 266 days.

Ten dummy variables are created depending on the period in which the fetus was exposed to Ramadan: conceived during Ramadan and exposed to Ramadan during month 1 to month 9 in utero. The control group consists of those children who were not exposed to Ramadan, that is, children who were conceived just after Ramadan and born before the following Ramadan.[7] Figure 1 demonstrates how we determine exposure to fasting using the individual's date of birth. The shaded areas indicate the month of fasting (Ramadan), a diamond indicates the date of conception and a star denotes the date of birth.

[7] Van Ewijk (2011) argues that, for those children who were born within 21 days of the end of Ramadan but remained in utero relatively longer, it would be erroneous to consider them *not* exposed to Ramadan. However, the study considers a period of less than or equal to 21 days after Ramadan to be a safe margin for conception because it is rare for pregnancy to last three weeks beyond the average period of 266 days.

Figure 1: Exposure to fasting, based on birth date



Source: Van Ewijk et al. (2013).

3.2. Health Outcome Measures

Various studies have linked exposure to Ramadan in utero to different outcomes, including academic performance, anthropometric development and general health as well as short-term impacts such as birth weight. We focus on the anthropometric status of children aged 0–5 years, which provides a clear picture of the association between exposure to Ramadan in utero and children's anthropometric development. The data for height-for-age and weight-for-age is taken as z-scores from the MICS Punjab for 2008 and 2011.

3.3. Statistical Methods

Recent studies such as van Ewijk (2011) and Almond and Mazumder (2011) have used the ITT framework to compare outcomes between subjects who were prenatally exposed to Ramadan (treatment group) to those who were not (control group).[8] As a statistical concept, ITT can be used to overcome the problems arising in randomized control trials, such as noncompliance and missing outcome data (Gupta 2011). This approach incorporates all randomized subjects in groups to which they are randomly assigned regardless of noncompliance, protocol deviation, withdrawal and events post-randomization.

According to Fisher et al. (1990), ITT accounts for all random patients in groups to which they are randomly assigned regardless of whether (i) the

[8] Almond and Mazumder (2011) estimate the reduced-form effect of Ramadan timing by taking into consideration those births for which the in utero period overlapped with the month of Ramadan. They assume that the timing of Ramadan in relation to pregnancy is exogenous, whereas the decision to fast is endogenous.

treatment group *received* treatment and (ii) subjects later withdrew from the treatment. As Lachin (2000) notes, ITT analysis is considered unbiased if all the patients randomly allocated into groups are included in the analysis and followed from the outset regardless of whether one takes noncompliance into account. This not only minimizes the potential bias inherent in analyzing the treatment effect due to efficacy subset selection, but it also increases the power of the trial by including all patients, which increases the sample size of the experiment.

It is important to emphasize that the ITT approach overcomes the problem of noncompliance by considering *all* subjects, even if they do not comply with the treatment at later stages of the experiment. However, for this approach to be valid, subjects should not self-select into either the treatment or control group at the start of the experiment, that is, there should be no self-selection bias. The allocation of subjects into treatment and control groups must be a randomized process.

Van Ewijk (2011) points out that the selection bias problem may still exist if parents selectively time their pregnancy to avoid Ramadan, implying that their children will likely have better health anyway, their health-conscious parents having self-selected into the control group. If this is the case, children who were not exposed will be healthier simply because their fetal environment was more conducive to good health and not necessarily because they have avoided exposure to Ramadan. A selection bias would lead to a downward bias in the results – exaggerating the impact of Ramadan – because the omitted variable (selective timing of pregnancy) is positively related to child health outcomes but negatively related to exposure to fasting.

Similar to van Ewijk (2011) and Almond and Mazumder (2011), our study also uses the ITT approach, in accordance with which, children whose period in utero overlapped with the month of Ramadan are allocated to the treatment group regardless of the noncompliance that might exist if the sampled mothers were pregnant during Ramadan but not fasting. Almond et al. (2015) observe that fasting rates are rarely unity and, therefore, the ITT approach will underestimate the treatment effect of fasting. As discussed earlier, for ITT analysis to be valid, parents must not have timed their pregnancy to avoid Ramadan. If they timed conception such that it fell outside of Ramadan, this will give rise to self-selection bias.

Moving forward, it is important to understand that the results of this study should be interpreted as the average impact of all behaviors associated with the month of fasting – and not just the prenatal impact of fasting itself on child health outcomes. First, not all pregnant women fast and so, this average impact includes imperfect compliance. Second, there are other customs involved in observing Ramadan that may be relevant, such as changes in sleep patterns, changes in the quantity and quality of food intake and altered timings of nutritional intake relative to the rest of the year.

We employ the following model to analyze the impact of prenatal exposure to fasting in Ramadan on child health outcomes:

Health outcomes = f (month-of-fasting exposure measures, household-specific variables, mother-specific variables, child-specific variables)

The specific ordinary least squares (OLS) and fixed effects (FE) regression equations are described below.

3.3.1. OLS Regression Equations

The OLS regression model is:

Child health outcomes = $\beta_0 + \pi$ exposure variables + child controls + mother controls + household controls + error term (1)

$$CHO = \beta_0 + \pi E_i + \gamma C_i + \alpha M_i + \lambda X_i + \varepsilon_i$$

where CHO denotes child health outcomes, defined as either height-for-age or weight-for-age, E is a vector for exposure variables, and C, M and X are vectors for child-specific, mother-specific and household-specific controls, respectively. E includes categorical variables for exposure to fasting in Ramadan, with the following categories as treatment group variables:

- *month0*: conceived during Ramadan
- *month1*: exposed to Ramadan in the first month of pregnancy
- *month2*: exposed to Ramadan in the second month of pregnancy
- *month3*: exposed to Ramadan in the third month of pregnancy
- *month4*: exposed to Ramadan in the fourth month of pregnancy

- *month5*: exposed to Ramadan in the fifth month of pregnancy
- *month6*: exposed to Ramadan in the sixth month of pregnancy
- *month7*: exposed to Ramadan in the seventh month of pregnancy
- *month8*: exposed to Ramadan in the eighth month of pregnancy
- *month9*: exposed to Ramadan in the ninth month of pregnancy

The control group (excluded category) is denoted by *notexposed* (not exposed to Ramadan in utero).

The child-specific (C) controls include the child's age in months and age squared; dummy variables for gender (male = 1), birth year and birth month; birth order; mother's age at child's birth; and mother's age at child's birth squared. The mother-specific (M) control is the mother's education level. The household-specific (H) controls include the household head's education level, dummy variables for region (urban = 1) and district, wealth group (quintile), a dummy variable for landholding status (owns land = 1), number of children in the household and its ethnic background (categories).[9]

The two regression equations use different measures of health outcomes, but have similar independent variables. The two measures of health outcomes are:

- Height: height for age z-score (HAZ)
- Weight: weight for age z-score (WAZ)

Since our objective is to analyze the impact of prenatal exposure to Ramadan on child health outcomes, the main variables of interest are *month0* to *month9*, which represent the various periods in which the fetus was exposed to Ramadan in utero. These variables are compared with the control group (those children who were not prenatally exposed to Ramadan). To separate out the impact of seasonality from that of exposure to Ramadan, we include children's month of birth in the equation. The district and year interaction variable helps separate out the impact of other shocks such as floods or drought that may be specific to a given district.

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[9] Ethnicity and religion are not linked because about 95 percent of Pakistan's population is Muslim, regardless of ethnicity.

3.3.2. FE Regression Equations

Next, we estimate a model with household fixed effects (HFE), represented by γ_f (equations 2a and 2b below). This allows us to filter out any systematic between-family differences arising from the impact of all time-invariant factors common to a household, that is, we exclude the household-specific controls. Finally, we estimate a model using mother fixed effects (MFE), which excludes both the mother-specific and household-specific controls (equations 3a and 3b below). Since it is possible that more than one family might live in a household, the HFE model estimates the average variation across children living in a household (they might have different mothers). The MFE model estimates the average variation across children from the same mother, filtering out any between-mothers differences arising from time-invariant factors related to the mother, such as her education level.

The HFE model is:

Child health outcomes = $\beta_0 + \pi$ exposure variables + child controls + mother controls + γ_f + error term (2)

$$HAZ_i = \beta_0 + \beta_1 month0_i + \beta_2 month1_i + \beta_3 month2_i + \beta_4 month3_i + \beta_5 month4_i + \beta_6 month5_i + \beta_7 month6_i + \beta_8 month7_i + \beta_9 month8_i + \beta_{10} month9_i + \gamma C_i + \alpha M_i + \gamma_f + \varepsilon_i \quad (2a)$$

$$WAZ_i = \beta_0 + \beta_1 month0_i + \beta_2 month1_i + \beta_3 month2_i + \beta_4 month3_i + \beta_5 month4_i + \beta_6 month5_i + \beta_7 month6_i + \beta_8 month7_i + \beta_9 month8_i + \beta_{10} month9_i + \gamma C_i + \alpha M_i + \gamma_f + \varepsilon_i \quad (2b)$$

The MFE model is:

Child health outcomes = $\beta_0 + \pi$ exposure variables + child controls + γ_f + error term (3)

$$HAZ_i = \beta_0 + \beta_1 month0_i + \beta_2 month1_i + \beta_3 month2_i + \beta_4 month3_i + \beta_5 month4_i + \beta_6 month5_i + \beta_7 month6_i + \beta_8 month7_i + \beta_9 month8_i + \beta_{10} month9_i + \gamma C_i + \gamma_f + \varepsilon_i \quad (3a)$$

$$WAZ_i = \beta_0 + \beta_1 month0_i + \beta_2 month1_i + \beta_3 month2_i + \beta_4 month3_i + \beta_5 month4_i + \beta_6 month5_i + \beta_7 month6_i + \beta_8 month7_i + \beta_9 month8_i + \beta_{10} month9_i + \gamma C_i + \gamma_f + \varepsilon_i \quad (3b)$$

The study also aims to compare the impact of prenatal exposure to Ramadan on child anthropometric outcomes across various factors, including income group, parental education level and ethnic group. This enables a deeper analysis of how the impact of prenatal exposure to fasting varies across households by income group, parental education and ethnicity.

4. Data

The study draws on two rounds of the MICS dataset for Punjab to examine the impact of prenatal exposure to Ramadan on child health.[10] The dataset comprises a pooled cross-section of all the households in Punjab that were surveyed under the MICS initiative in 2008 and 2011. It provides data for all the key variables we need (children's date, month and year of birth) to generate the main variable of interest: children's prenatal exposure to Ramadan. The MICS dataset, which covers 137,500 children under the age of five, also provides information on variables related to the child health outcomes being gauged here. Table A1 in the Appendix gives the descriptive statistics of the sample data.

The two measures of child health outcomes – the study's dependent variables – capture both the long- and short-term health outcomes of children under five in the form of their HAZ and WAZ scores.[11] Z-scores are a standardized way of measuring anthropometric status because they compare the sampled children with the international reference group of children of the same gender and age. It is essential to analyze the impact of prenatal exposure on both measures because height is a long-term indicator, whereas weight is a short-term indicator of health outcomes (weight can vary due to factors such as illness in the short term). Height is important because the fetus grows in length throughout the period of gestation, but gains weight mostly in the last trimester, which is a relatively less important period of development compared to the first and second trimesters.

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[10] The MICS is an international household survey program initiated by UNICEF. It aims to provide data on women and children in different countries to monitor their status vis-à-vis progress against the Millennium Development Goals. In Pakistan, the MICS for Punjab was carried out by the Bureau of Statistics (Government of Punjab), with technical expertise provided by UNICEF and UNDP.

[11] According to the World Health Organization, z-scores (or standard deviation scores) measure the difference between observed and average values for a reference population in standard deviation units.

Using ten measures of the exposure variable allows us to gauge which month of a certain trimester is important in terms of the impact of exposure on fetal development.[12] We also analyze how the impact of exposure shifts between months by using different estimation techniques. Almond and Mazumder (2011) and Almond et al. (2015) have used nine indicators of exposure to fasting.[13]

5. Empirical Results

This section describes the study's results, based on the models developed in Section 3.

5.1. Impact of Exposure to Fasting on Child Health Outcomes

We start by running a simple OLS regression to establish the correlation between the prenatal exposure variables and children's anthropometric status.[14] This allows us to estimate the average variation in health outcomes across all the children in our dataset. Next, we control for child- and mother-specific factors and for household-specific demographic and socioeconomic factors that might be correlated to child health outcomes in the regression.[15]

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[12] As a robustness check, we also estimate the models using three dummies (for the first, second and third trimesters). In the OLS specifications, exposure in the first and second trimesters is negatively related to HAZ, whereas exposure in the third trimester is positively related to both HAZ and WAZ. In the FE regressions, exposure in the first two trimesters has a negative impact on HAZ, but no significant impact on WAZ.

[13] Almond and Mazumder (2011) state: 'Our simplest measure is an indicator for whether Ramadan overlapped with pregnancy. We also construct indicators for whether Ramadan occurred during the first, second, or third trimester. Although these basic measures are easy to interpret, they may not be suited to capture effects that occur during narrowly defined "critical windows" of fetal development.'

[14] The correlation between prenatal exposure to Ramadan and child health outcomes reveals that exposure during the first and second trimesters (months 0 to 6) is mostly negatively related to child health outcomes. However, exposure in the last three months is positively related to the latter. This is not completely at odds with the literature, which suggests that exposure to fasting during early pregnancy has negative implications because, by the end of the second trimester, all fetal organs have been developed; in the third trimester, the fetus grows and matures. The first trimester is the embryonic stage in which its major organs develop. This stage is crucial because any shock – for example, in terms of infectious diseases or radiation – can severely damage the embryo. The medical literature supports similar findings.

[15] The control variables used in the literature include the child's age and age squared, the child's gender and month/year of birth, birth order, the mother's age at childbirth and age squared, the

In the case of height-for-age, after controlling for child, mother and household characteristics (Table 1, column 1), we observe that children who were prenatally exposed to fasting had lower HAZ scores on average if they were exposed in the first two trimesters (months 1–6), relative to nonexposed children. The largest change occurs if exposure was in the fourth month, leading to a reduction in HAZ of 0.3 standard deviations. This could be for two reasons. First, early pregnancy is more critical to long-term development, so that nutritional disruptions are more detrimental to the fetus in this key period. Second, women may be more likely to fast in earlier stages of pregnancy.[16]

However, children who were prenatally exposed in the ninth month (born during Ramadan) were, on average, taller than nonexposed children. This could be a result of higher consumption of food, particularly meat, when celebrating Eid (at the end of Ramadan). In the third trimester more generally, pregnancy is more visible and family members might be more likely to look after the mother, implying greater food intake and thus diminishing the impact of Ramadan. It could also be that women are less likely to fast in the third trimester.

The maternal education and household socioeconomic status variables are significant and, as expected, have a positive relationship with HAZ. The other controls incorporated in the model also bear the expected signs: a higher birth order, for example, is negatively associated with HAZ, while landholding is positively related to HAZ. In the last two columns of Table 1, we see that the results for HAZ remain similar if we include fixed effects such as the interaction of the district*urban and district*year dummy variables. The district and year interaction variables are included to separate out the impact of any shocks – for example, floods or drought – specific to a given district. The month dummies help filter out the impact of seasonality.

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mother and household head's education level, urban status, district, wealth quintile and ethnicity (see Almond et al. 2015; Almond and Mazumder 2008; van Ewijk 2011; Greve et al. 2015).

[16] The incidence of fasting may be highest during early pregnancy, when mothers may not be aware that they are pregnant because it is not yet visible (Almond and Mazumder 2011).

Table 1: OLS regression: height-for-age

Variable	HAZ	HAZ with district and urban interactions	HAZ with district and year interactions
Month 9	0.0872***	0.0860***	0.0790***
	(0.0224)	(0.0224)	(0.0223)
Month 8	0.0396	0.0378	0.0314
	(0.0273)	(0.0273)	(0.0272)
Month 7	-0.0189	-0.0185	-0.0338
	(0.0324)	(0.0324)	(0.0323)
Month 6	-0.127***	-0.127***	-0.138***
	(0.0356)	(0.0356)	(0.0355)
Month 5	-0.216***	-0.214***	-0.220***
	(0.0350)	(0.0350)	(0.0349)
Month 4	-0.313***	-0.310***	-0.318***
	(0.0334)	(0.0334)	(0.0334)
Month 3	-0.232***	-0.231***	-0.236***
	(0.0316)	(0.0316)	(0.0316)
Month 2	-0.139***	-0.137***	-0.137***
	(0.0294)	(0.0294)	(0.0294)
Month 1	-0.0537**	-0.0505*	-0.0524*
	(0.0269)	(0.0269)	(0.0269)
Month 0	-0.0349	-0.0345	-0.0360
	(0.0226)	(0.0226)	(0.0225)
Constant	-2.374***	-2.389***	-2.473***
	(0.117)	(0.118)	(0.141)
Child controls	Yes	Yes	Yes
Mother controls	Yes	Yes	Yes
Household controls	Yes	Yes	Yes
Observations	102,734	102,734	102,734
R-squared	0.112	0.114	0.123

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2 estimates the relationship between weight-for-age and prenatal exposure to Ramadan, controlling for child, mother and household characteristics. Prenatal exposure to fasting has a negative impact on WAZ during months 3–5, but a positive effect in month 9.

Table 2: OLS regression: weight-for-age

Variable	WAZ	WAZ with district and urban interactions	WAZ with district and year interactions
Month 9	0.0604***	0.0588***	0.0574***
	(0.0165)	(0.0164)	(0.0165)
Month 8	0.0122	0.0112	0.00601
	(0.0203)	(0.0203)	(0.0203)
Month 7	0.000140	-0.000906	-0.00977
	(0.0238)	(0.0237)	(0.0238)
Month 6	-0.00596	-0.00720	-0.0167
	(0.0258)	(0.0257)	(0.0258)
Month 5	-0.0475*	-0.0473*	-0.0552**
	(0.0254)	(0.0254)	(0.0254)
Month 4	-0.116***	-0.114***	-0.120***
	(0.0245)	(0.0245)	(0.0245)
Month 3	-0.0890***	-0.0874***	-0.0917***
	(0.0233)	(0.0233)	(0.0233)
Month 2	-0.0279	-0.0264	-0.0319
	(0.0218)	(0.0217)	(0.0218)
Month 1	-0.0234	-0.0217	-0.0279
	(0.0200)	(0.0200)	(0.0200)
Month 0	0.00164	0.00169	-0.00393
	(0.0168)	(0.0168)	(0.0168)
Constant	-1.469***	-1.471***	-1.421***
	(0.0880)	(0.0888)	(0.105)
Child controls	Yes	Yes	Yes
Mother controls	Yes	Yes	Yes
Household controls	Yes	Yes	Yes
Observations	105,096	105,096	105,096
R-squared	0.135	0.137	0.142

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Similar results hold when we include the interaction of the district dummies with an urban dummy and year variables. It is worth noting that exposure in the ninth month is positively related to both health outcome measures. This could be because (i) women are less likely to fast so close to childbirth, (ii) women's food intake may increase during Eid (at the end of Ramadan), and (iii) most of the fetal development has already occurred in the first two trimesters and the fetus is now gaining weight at this stage.

The results of the OLS regressions indicate that prenatal exposure to fasting affects child health outcomes, especially during mid-pregnancy. However, this technique does not control for unobservable variables that might result in an omitted variable bias. To resolve this, we re-estimate the models using FE regression.

5.2. FE Specifications

Moving toward our main analysis, the FE approach shows how controlling for time-invariant unobservable variables within either the broader household (HFE) or nuclear family (MFE) affects the estimates (van Ewijk 2011). The HFE estimates help separate out any systematic within-family differences. The MFE estimates compare children from the same mother and are not, therefore, sensitive to any systematic differences within mothers in terms of maternal health (van Ewijk 2011). Since FE regression controls for omitted, time-invariant variables within the household, it yields better estimates of the impact of exposure to fasting on child health outcomes.

The HFE and MFE estimates in Table 3 indicate that prenatal exposure to fasting in months 1–7 has a negative impact on children's height-for-age relative to that of nonexposed children.

Table 3: Height-for-age FE

Variable	HAZ with HFE	HAZ with MFE
Month 9	0.0471	0.0469
	(0.0314)	(0.0332)
Month 8	-0.0113	-0.00715
	(0.0389)	(0.0413)
Month 7	-0.117**	-0.102**
	(0.0460)	(0.0486)
Month 6	-0.165***	-0.165***
	(0.0493)	(0.0521)
Month 5	-0.274***	-0.279***
	(0.0482)	(0.0509)
Month 4	-0.307***	-0.317***
	(0.0462)	(0.0486)
Month 3	-0.226***	-0.247***
	(0.0442)	(0.0465)
Month 2	-0.154***	-0.163***
	(0.0415)	(0.0437)

Variable	HAZ with HFE	HAZ with MFE
Month 1	-0.0766**	-0.0833**
	(0.0377)	(0.0397)
Month 0	0.00449	0.0109
	(0.0319)	(0.0337)
Constant	-6.367***	-7.796***
	(0.783)	(1.398)
Child controls	Yes	Yes
Mother controls	Yes	No
Household controls	No	No
Observations	102,734	102,734
R-squared	0.104	0.115
Number of MFE		69,506
Number of HFE	64,807	

Note: Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

The WAZ estimates show that children who were prenatally exposed to fasting in months 5–8 were, on average, more underweight than those who were not exposed (Table 4). A possible reason for this negative impact on weight-for-age is that the third trimester involves primarily fetal weight-gain and thus exposure to fasting at this stage will likely have a negative effect on the baby's weight.[17]

Table 4: Weight-for-age FE

Variable	WAZ with HFE	WAZ with MFE
Month 9	0.0104	0.0155
	(0.0230)	(0.0242)
Month 8	-0.0891***	-0.0841***
	(0.0284)	(0.0300)
Month 7	-0.106***	-0.106***
	(0.0336)	(0.0353)
Month 6	-0.102***	-0.100***
	(0.0359)	(0.0378)
Month 5	-0.0909***	-0.0894**
	(0.0352)	(0.0369)
Month 4	-0.0473	-0.0536
	(0.0337)	(0.0353)

[17] In both OLS and FE, WAZ is affected positively by exposure in month 9, but this result loses statistical significance in the FE specifications. Since the FE regression relies on the variation between children from the same household or mother, the sample variability decreases and standard errors increase.

Variable	**WAZ with HFE**	**WAZ with MFE**
Month 3	-0.0366	-0.0416
	(0.0322)	(0.0337)
Month 2	-0.00846	-0.00877
	(0.0303)	(0.0317)
Month 1	0.0224	0.0229
	(0.0275)	(0.0289)
Month 0	0.0223	0.0329
	(0.0234)	(0.0245)
Constant	-9.863***	-10.38***
	(0.571)	(1.018)
Child controls	Yes	Yes
Mother controls	Yes	No
Household controls	No	No
Observations	105,096	105,096
R-squared	0.133	0.145
Number of MFE		70,723
Number of HFE	65,898	

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

It is important to note that height-for-age is a measure of long-term health whereas weight-for-age is a measure of short-term health, since the latter can also be affected if the child is suffering from a disease (such as diarrhea) at the time. Even after controlling for time-invariant omitted variables, the pattern of results is stronger than in the OLS regressions, especially in the case of HAZ, suggesting that these results are robust. In the case of the WAZ results, the statistically significant impact of Ramadan moves from mid-pregnancy (in the OLS specifications) to later in the pregnancy (FE specifications).

We have greater confidence in the FE results because they control better for unobserved heterogeneity. The F-test results for the joint significance of the FE estimates suggest they are better. The FE results for WAZ also reflect what is medically known about the stages of fetal development. Here, it is important to note that FE focuses on the variation between children from the same mother (in the MFE case) and ignores the variation across all the children in the dataset, yielding higher standard errors than those generated by the OLS models. Thus, the FE specifications solve for the omitted variable bias, but at the expense of greater variability in the sample and lower standard errors.

5.3. Analysis within Subgroups

For a deeper analysis of the link between prenatal exposure to Ramadan and child health outcomes, we estimate the impact of exposure separately for a variety of subsamples to gauge whether the impact of exposure to fasting varies, based on certain household attributes. This subgroup analysis allows all parameters to differ across groups. For instance, the impact of prenatal exposure to fasting on child health can differ across ethnic groups or wealth quintiles. In the latter case, women from high wealth quintile households are less likely to fast or more likely to compensate for lost nutrients if they do fast, implying that children from high wealth quintile households are less affected by prenatal exposure to fasting than those from low wealth quintile households.

This exercise is carried out by dividing the sample into subsamples based on: (i) wealth quartile, (ii) the mother's education level, (iii) the household head's education level, and (iv) ethnic group. We carry out OLS regressions that include all the control variables. These results estimate health outcome variations across all the children in the dataset rather than just variations across children from the same mother or household.

The results in Table 5 indicate that children who belong to families in the lowest wealth quintile through the fourth wealth quintile are, on average, shorter if they were prenatally exposed to Ramadan in the first two trimesters. However, the HAZ of children from families in the highest wealth quintile is negatively affected only if exposure to fasting occurred in month 4.

Table 5: Height-for-age: wealth group regressions

Variable	Lowest	Second	Middle	Fourth	Highest
Month 9	0.146***	0.166***	0.0449	0.0208	0.109**
	(0.0549)	(0.0503)	(0.0476)	(0.0468)	(0.0518)
Month 8	0.0970	0.105*	-0.0143	-0.0389	0.0918
	(0.0671)	(0.0631)	(0.0597)	(0.0567)	(0.0613)
Month 7	0.0510	0.0560	-0.0970	-0.139**	0.0898
	(0.0781)	(0.0757)	(0.0696)	(0.0673)	(0.0746)
Month 6	-0.144*	-0.0102	-0.201***	-0.168**	-0.0472
	(0.0843)	(0.0824)	(0.0763)	(0.0748)	(0.0835)
Month 5	-0.360***	-0.225***	-0.254***	-0.171**	-0.0537
	(0.0808)	(0.0800)	(0.0758)	(0.0745)	(0.0825)

Variable	Lowest	Second	Middle	Fourth	Highest
Month 4	-0.410***	-0.238***	-0.370***	-0.311***	-0.191**
	(0.0771)	(0.0755)	(0.0728)	(0.0711)	(0.0798)
Month 3	-0.372***	-0.182***	-0.222***	-0.251***	-0.103
	(0.0696)	(0.0695)	(0.0706)	(0.0675)	(0.0795)
Month 2	-0.193***	-0.101	-0.132**	-0.166**	-0.0500
	(0.0647)	(0.0636)	(0.0646)	(0.0646)	(0.0732)
Month 1	-0.102*	-0.0115	-0.0930	-0.123**	0.105
	(0.0601)	(0.0577)	(0.0580)	(0.0600)	(0.0664)
Month 0	0.0398	-0.0385	-0.0490	-0.0776	-0.0184
	(0.0531)	(0.0497)	(0.0476)	(0.0492)	(0.0545)
Constant	-2.182***	-2.277***	-1.996***	-2.012***	-1.949***
	(0.284)	(0.267)	(0.253)	(0.260)	(0.318)
Observations	18,573	19,794	21,569	22,817	20,010
R-squared	0.082	0.091	0.080	0.074	0.058

Table 6 indicates that children who belong to families in the lowest wealth quintile have, on average, a lower WAZ if they were exposed to Ramadan in the first two trimesters. Children from families in the highest wealth quintile are not affected negatively by exposure to fasting.

Table 6: Weight-for-age: wealth group regressions

Variable	Lowest	Second	Middle	Fourth	Highest
Month 9	0.0965**	0.0969***	0.0601*	0.00625	0.0719*
	(0.0400)	(0.0359)	(0.0357)	(0.0349)	(0.0386)
Month 8	0.0515	0.0388	-0.0275	-0.00709	0.0411
	(0.0489)	(0.0465)	(0.0437)	(0.0430)	(0.0466)
Month 7	0.0223	0.0166	0.0192	-0.0273	0.000661
	(0.0571)	(0.0529)	(0.0511)	(0.0508)	(0.0554)
Month 6	-0.0351	0.0605	0.0316	-0.0472	0.0135
	(0.0601)	(0.0581)	(0.0556)	(0.0548)	(0.0613)
Month 5	-0.146**	-0.0548	0.0290	-0.0166	-0.0313
	(0.0580)	(0.0564)	(0.0559)	(0.0549)	(0.0607)
Month 4	-0.219***	-0.0805	-0.0847	-0.119**	-0.0419
	(0.0560)	(0.0545)	(0.0533)	(0.0531)	(0.0598)
Month 3	-0.225***	-0.114**	0.00150	-0.0739	-0.0183
	(0.0508)	(0.0498)	(0.0512)	(0.0515)	(0.0596)
Month 2	-0.0921*	-0.0392	-0.0228	-0.0103	0.0670
	(0.0474)	(0.0460)	(0.0475)	(0.0487)	(0.0551)
Month 1	-0.00152	-0.0180	-0.0406	-0.0595	0.0351
	(0.0436)	(0.0425)	(0.0436)	(0.0460)	(0.0495)

Variable	Lowest	Second	Middle	Fourth	Highest
Month 0	0.0457	-0.00424	0.0106	-0.0229	-0.00271
	(0.0391)	(0.0364)	(0.0360)	(0.0364)	(0.0410)
Constant	-1.068***	-1.337***	-1.432***	-1.247***	-1.419***
	(0.214)	(0.193)	(0.193)	(0.194)	(0.245)
Observations	19,125	20,240	22,014	23,268	20,480
R-squared	0.102	0.102	0.089	0.096	0.071

Interesting results emerge when we look at mothers with different levels of education. Table 7 indicates that children born to mothers with less than or up to secondary schooling are more likely to be affected negatively by exposure to Ramadan in the first two trimesters. Children born to mothers with less than primary schooling are, on average, shorter if they were prenatally exposed to fasting in the first two trimesters, compared to children who were not exposed.

Table 7: Height-for-age: mother's education level

Variable	None	Primary	Middle	Secondary	Higher
Month 9	0.139***	0.0329	0.0180	0.0397	0.0794
	(0.0325)	(0.0512)	(0.0696)	(0.0612)	(0.0704)
Month 8	0.0747*	-0.0277	-0.112	0.00224	0.149*
	(0.0402)	(0.0622)	(0.0855)	(0.0742)	(0.0833)
Month 7	0.0538	-0.184**	-0.226**	-0.0754	0.156
	(0.0471)	(0.0750)	(0.101)	(0.0900)	(0.100)
Month 6	-0.0752	-0.253***	-0.364***	-0.142	0.0589
	(0.0512)	(0.0829)	(0.111)	(0.102)	(0.111)
Month 5	-0.236***	-0.249***	-0.267**	-0.231**	0.00820
	(0.0495)	(0.0823)	(0.113)	(0.100)	(0.112)
Month 4	-0.325***	-0.334***	-0.366***	-0.276***	-0.172
	(0.0464)	(0.0806)	(0.107)	(0.0978)	(0.109)
Month 3	-0.293***	-0.251***	-0.204*	-0.0917	-0.0670
	(0.0429)	(0.0781)	(0.105)	(0.0958)	(0.105)
Month 2	-0.160***	-0.192***	-0.0988	-0.0194	-0.0759
	(0.0400)	(0.0724)	(0.0992)	(0.0872)	(0.100)
Month 1	-0.0637*	-0.0912	-0.0549	0.0223	-0.0201
	(0.0366)	(0.0655)	(0.0894)	(0.0821)	(0.0878)
Month 0	-0.0297	-0.101*	0.0343	0.0135	-0.0561
	(0.0318)	(0.0523)	(0.0714)	(0.0655)	(0.0750)
Constant	-2.498***	-1.730***	-2.112***	-2.253***	-3.043***
	(0.161)	(0.285)	(0.410)	(0.427)	(0.522)
Observations	51,094	18,219	9,710	13,088	10,623
R-squared	0.089	0.079	0.081	0.065	0.061

The results for the subsample of the least educated women are stronger than in the OLS regressions for the full sample and somewhat closer to the FE coefficients. This may be because the unobservables controlled for in the FE regressions were correlated with the mother's education. However, children born to mothers with the highest level of education are not affected negatively by prenatal exposure to Ramadan. Table 8 gives similar results for WAZ.

Table 8: Weight-for-age: mother's education level

Variable	None	Primary	Middle	Secondary	Highest
Month 9	0.0989***	0.00462	0.0251	-0.0147	0.0794
	(0.0235)	(0.0376)	(0.0531)	(0.0461)	(0.0704)
Month 8	0.0256	0.0174	-0.120*	-0.0238	0.149*
	(0.0291)	(0.0480)	(0.0655)	(0.0566)	(0.0833)
Month 7	0.0438	-0.0394	-0.208***	-0.0411	0.156
	(0.0339)	(0.0556)	(0.0751)	(0.0668)	(0.100)
Month 6	0.0382	-0.0491	-0.215***	-0.0840	0.0589
	(0.0364)	(0.0613)	(0.0813)	(0.0728)	(0.111)
Month 5	-0.0228	-0.0320	-0.286***	-0.102	0.00820
	(0.0352)	(0.0610)	(0.0805)	(0.0734)	(0.112)
Month 4	-0.0998***	-0.116*	-0.278***	-0.164**	-0.172
	(0.0338)	(0.0601)	(0.0776)	(0.0702)	(0.109)
Month 3	-0.0978***	-0.0908	-0.223***	-0.0126	-0.0670
	(0.0313)	(0.0587)	(0.0753)	(0.0694)	(0.105)
Month 2	-0.0317	-0.0718	-0.115	0.0727	-0.0759
	(0.0291)	(0.0540)	(0.0717)	(0.0655)	(0.100)
Month 1	-0.00626	-0.0557	-0.0993	0.00260	-0.0201
	(0.0268)	(0.0492)	(0.0657)	(0.0611)	(0.0878)
Month 0	0.0122	-0.0212	-0.0136	0.0431	-0.0561
	(0.0236)	(0.0384)	(0.0544)	(0.0483)	(0.0750)
Constant	-1.412***	-1.195***	-0.964***	-1.673***	-3.043***
	(0.119)	(0.208)	(0.326)	(0.313)	(0.522)
Observations	52,389	18,567	9,878	13,384	10,623
R-squared	0.108	0.100	0.117	0.078	0.061

One explanation for these results is that better educated women from wealthier households are more aware of the health implications of fasting: they are thus less likely to fast or, if they do fast, more likely to take nutritional supplements to counter the negative impact of fasting. Similar results emerge when we consider different levels of education across household heads and how this relates to the incidence of maternal fasting, although these are not as stark.

For estimates across ethnic groups, we observe that the HAZ of children from Punjabi and Seraiki backgrounds is affected negatively by exposure to Ramadan in the first two trimesters. Prenatal exposure to fasting appears to have no impact on children from Urdu-speaking families, but this may be because the data provides only a very small number of observations for this ethnic group.

In addition to running separate regressions for these subsamples, we carry out regressions for the full sample, similar to the earlier OLS regressions, but with the addition of exposure variables interacting with dummy variables for the characteristics above (for example, the interaction between the five wealth quintile dummies and the ten exposure variables). The advantage of interaction effects is that they allow us to use the full sample in determining how demographics affect the exposure variables and to gauge if the differences in the treatment effects between different demographic groups are statistically significant. The results indicate that children who belong to the third wealth quintile or higher are, on average, shorter if they were exposed to fasting in months 6–7, compared to children from the lowest wealth quintile.

5.4. Selective Timing of Pregnancy

Estimates of the impact on child health outcomes of prenatal exposure to fasting may be biased if parents have selectively timed their pregnancy with respect to Ramadan. To counter this concern, we compare estimates across parental characteristics, following van Ewijk (2011). We also conduct a robustness check by testing how the impact of exposure to Ramadan changes when we look at families least likely to time their pregnancies, that is, those not using modern methods of family planning. The estimations are also carried out specifically for firstborn children. Given that it is important to address the problem of self-selection to ensure that the use of ITT remains valid, these techniques help identify any corresponding bias in the results.

5.5. Comparing Parental Characteristics

Differences in parental characteristics may exist between parents who selectively time their pregnancy to avoid overlapping with Ramadan and those who do not. As Van Ewijk (2011) observes, better educated, more health-aware households are liable to plan their pregnancies such that they do not coincide with Ramadan. If this is the case, then the control group (not exposed to fasting) will have better health outcomes even in the absence of any effect of exposure to fasting.

Table 9 provides some interesting results in terms of parental characteristics such as the household head and mother's level of education, wealth quintile and ethnicity. The results indicate that children from households whose head is uneducated are less likely to have been exposed to fasting. Children from households whose head has completed primary school or higher are, however, more likely to have been exposed to fasting. Similarly, children born to uneducated mothers are less likely to have been exposed, but those born to mothers with secondary schooling or higher are more likely to have been exposed to fasting. Children from the second wealth quintile are less likely to have been exposed, unlike children from the highest wealth quintile, who are more likely to have been exposed to fasting.

Table 9: Parental characteristics

Variable		**Not exposed (%)**	**Exposed (%)**	**t-value**	**Pr(|T| > |t|)**
Household head's education	None*	42.9	41.5	-3.9629	0.0001
	Primary*	16.2	16.9	2.6845	0.0073
	Middle	12.6	12.8	0.8636	0.3878
	Secondary	18.2	18.2	-0.2293	0.8187
	Higher*	9.8	10.3	2.6092	0.0091
Mother's education	None*	54.9	52.0	-8.0748	0.0000
	Primary	16.8	17.2	1.3686	0.1711
	Middle	8.7	9.1	1.5750	0.1153
	Secondary*	10.8	12.1	5.4660	0.0000
	Higher*	8.5	9.5	4.8456	0.0000
Wealth quintiles	Lowest	20.1	19.9	-0.8872	0.3750
	Secondary*	20.4	19.6	-2.9056	0.0037
	Middle	20.9	20.5	-1.1182	0.2635
	Fourth	21.0	21.5	1.8907	0.0587
	Highest*	17.4	18.3	3.1679	0.0015
Ethnicity	Urdu*	4.5	4.8	1.9636	0.0496
	Punjabi	69.2	69.0	-0.7456	0.4559
	Seraiki	21.7	21.3	-1.4713	0.1412

Note: * denotes significant difference between treatment and control groups.

These results are the opposite of what we would expect if we assumed that better educated parents were more likely to selectively time their pregnancy to avoid Ramadan. A possible explanation lies in the 'culling effect' described by Almond and Currie (2011), which arises because weaker fetuses are less likely to survive exogenous shocks. Since the data relates to children who have already survived such shocks, the proportion of such children is smaller for poorer, uneducated families. The culling effect would then imply that the impact of exposure to fasting is underestimated if weaker fetuses are miscarried when exposed to shocks.

For a deeper understanding of selectivity, we compare parental characteristics in relation to exposure across trimesters. While these findings are generally consistent with the results in Table 9, they offer some additional insights. As Table 10 shows, children born to mothers with less than primary schooling are more likely to be nonexposed, but if they were exposed to fasting, it was more likely to have been in the first trimester. Moreover, exposure in the second and third trimesters is positively related to the mother's level of education. Finally, children from wealthier households are more likely to be nonexposed, or if exposed, would have been so in the third trimester.

Table 10: Parental characteristics across trimesters

Variable	First trimester	Second trimester	Third trimester	Not exposed
Mother's education				
Primary	-0.00699**	0.00860**	0.00695*	-0.0136***
	(0.00341)	(0.00362)	(0.00383)	(0.00323)
Middle	-0.0117***	0.0195***	0.00593	-0.0172***
	(0.00443)	(0.00481)	(0.00501)	(0.00427)
Secondary	-0.0137***	0.0125***	0.0203***	-0.0289***
	(0.00426)	(0.00460)	(0.00488)	(0.00403)
Higher	-0.0145***	0.0227***	0.0188***	-0.0301***
	(0.00500)	(0.00547)	(0.00574)	(0.00478)
Household head's education				
Primary	0.0151***	-0.00236	-0.00672*	0.00921***
	(0.00340)	(0.00362)	(0.00379)	(0.00319)
Middle	0.0149***	-0.00509	-0.00845**	-0.00315
	(0.00378)	(0.00404)	(0.00425)	(0.00359)
Secondary	0.00872**	-0.00415	-0.00634	0.00358
	(0.00348)	(0.00374)	(0.00392)	(0.00337)

Variable	First trimester	Second trimester	Third trimester	Not exposed
Higher	0.0103**	-0.00592	-0.00653	-7.51e-05
	(0.00453)	(0.00487)	(0.00519)	(0.00429)
Wealth quintiles				
Second	-0.00166	-0.0111***	0.00324	0.00760**
	(0.00375)	(0.00396)	(0.00413)	(0.00355)
Middle	-0.00553	-0.00791*	0.00640	0.00825**
	(0.00384)	(0.00411)	(0.00427)	(0.00367)
Fourth	-0.00836**	-0.0116***	0.0160***	0.00699*
	(0.00405)	(0.00432)	(0.00453)	(0.00385)
Highest	-0.0134***	-0.0111**	0.0209***	0.0110**
	(0.00467)	(0.00502)	(0.00527)	(0.00444)
Constant	0.209***	0.250***	0.269***	0.190***
	(0.00273)	(0.00292)	(0.00300)	(0.00258)
Observations	127,607	127,607	127,607	127,607
R-squared	0.001	0.000	0.001	0.001

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.6. Estimation of Results for Children from Families That Have Never Used Birth Control

As a robustness check, we test how exposure to fasting is related to the use of family planning.[18] Table 11 gives the results of two separate regressions (for HAZ and WAZ) for families who report not using family planning. The results are interesting because they reveal that the HAZ of children from families who have never used family planning is affected negatively if they were exposed to fasting in months 4–8.

The WAZ is affected negatively if children were prenatally exposed to fasting in months 7 and 8, compared to nonexposed children. The magnitude of the coefficients is smaller for the given subsample than for the full sample. Had these magnitudes increased, this would suggest that households who use family planning are different from those who do not (that is, do not time their pregnancies).

[18] We categorize this data based on whether the woman and/or her husband reported ever having used family planning methods. Women whose response was ‘no’ fall within the subsample perceived to have never used birth control. Women whose response was ‘yes’ fall within the subsample of families that have used birth control at any point in time.

Table 11: Robustness checks based on sample of families not using birth control

Variable	HAZ	WAZ
Month 9	-0.0436	-0.0388
	(0.0412)	(0.0318)
Month 8	-0.169***	-0.118***
	(0.0549)	(0.0433)
Month 7	-0.255***	-0.171***
	(0.0666)	(0.0524)
Month 6	-0.239***	-0.0957
	(0.0806)	(0.0619)
Month 5	-0.154*	-0.0341
	(0.0789)	(0.0607)
Month 4	-0.158**	-0.0734
	(0.0715)	(0.0550)
Month 3	-0.0752	-0.0190
	(0.0651)	(0.0499)
Month 2	-0.00800	0.0215
	(0.0599)	(0.0455)
Month 1	-0.0520	-0.00648
	(0.0525)	(0.0401)
Month 0	-0.0596	0.000502
	(0.0415)	(0.0315)
Constant	-2.292***	-5.483***
	(0.452)	(0.352)
Child controls	Yes	Yes
Mother controls	Yes	Yes
Household controls	Yes	Yes
Observations	31,705	32,007
R-squared	0.140	0.171

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

First-born children are less likely to have been timed because we assume that people are keen to have their first child soon after marriage. Couples are more likely then, to use birth control after their first child. This method is used as a robustness check to see how the impact of exposure to fasting changes across first-born children. We find that children who were exposed in month 4 are, on average, shorter than nonexposed children. Children who were prenatally exposed to fasting in month 8 are slightly taller than their nonexposed peers. There is, however, no difference in weight between exposed and nonexposed first-born children.

6. Conclusion

This study investigates the association between fetal exposure to fasting and child health outcomes in terms of height-for-age and weight-for-age (measured as z-scores). Our findings show that children who were prenatally exposed to Ramadan in the first or second trimesters are shorter, on average. Children exposed to prenatal fasting between the third and fifth months of pregnancy are, on average, underweight compared to their nonexposed peers.

On using HFE and MFE to test these results, we find that the negative impact on weight-for-age occurs with exposure in the fifth to eighth months of pregnancy. These results are in line with the literature, which suggests that shocks during pregnancy can alter fetal programming, with visibly adverse health outcomes later in life. The negative impact of fasting in Ramadan on child health outcomes stems not only from reduced caloric intake, but also from an increase in unhealthy eating habits, changes in sleep pattern and altered nutritional intake timings during this month. It is important to understand that the results of this study should be interpreted as the impact of *all* the activities associated with observing Ramadan. Following Almond et al. (2014), we do not separate out the impact of fasting alone. Our results emphasize that maternal nutritional intake – particularly during early pregnancy – is critical to long-term fetal development.

The study's findings imply that it is essential to introduce prenatal interventions that provide not only prenatal healthcare, but also help supplement maternal nutrition and create awareness among women and their families of how nutritional deficiencies in early pregnancy can have adverse implications for child health outcomes such as height and weight. Such interventions should ensure that women meet their nutritional requirements during pregnancy by avoiding missing meals and/or taking nutritional supplements.

Finally, we compare child health outcomes across different parental characteristics for subsamples exposed and not exposed to prenatal fasting. We also investigate the relationship between prenatal exposure to Ramadan and child health outcomes for families who do not practice family planning. In both cases, we find no evidence to suggest that women time their pregnancies selectively to avoid overlapping with Ramadan.

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Appendix

Table A1: Descriptive statistics

Variable	Obs.	Mean	SD	Min	Max
HAZ	119,967	-1.444247	1.645477	-5.99	5.99
WAZ	123,051	-1.51382	1.243558	-5.99	5.98
Month 9	127,888	0.0977105	0.296924	0	1
Month 8	127,888	0.0911501	0.28786346	0	1
Month 7	127,888	0.0910171	0.2876346	0	1
Month 6	127,888	0.09022665	0.2865643	0	1
Month 5	127,888	0.0830649	0.2759813	0	1
Month 4	127,888	0.0725009	0.2593166	0	1
Month 3	127,888	0.065182	0.2468478	0	1
Month 2	127,888	0.0671369	0.2502599	0	1
Month 1	127,888	0.0738615	0.2615464	0	1
Month 0	127,888	0.0840423	0.2774523	0	1
Not exposed	127,888	0.1854826	0.3886901	0	1
Gender	125,765	0.5119707	0.4998587	0	1
Urban	127,888	0.350893	0.4772514	0	1
Number of children	127,888	0.350893	0.4772514	0	1
Household owns land	127,836	0.3277559	0.46939	0	1
Child's age (months)	127,888	28.51777	17.9265	0	63
Mother's age at childbirth	109,349	27.88558	5.859597	10	50
Mother's education level	127,827	2.084395	1.389079	1	5
Household head's education level	127,654	2.383059	1.433371	1	5
Month of birth	127,888	6.57695	3.492464	1	12
Year of birth	127,888	2,007.06	2.280628	2003	2011
Birth order	127,888	3.208253	1.441108	1	5
District	127,888	16.32625	10.3912	1	36
Wealth group	127,888	2.98103	1.391674	1	5
Ethnicity	127,691	2.261506	0.6198215	1	4

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