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In utero Ramadan exposure and child nutrition

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Abstract

In this study, we empirically analyse whether *in utero* exposure to the Ramadan fasting period is negatively associated with child nutrition. The data for the analyses come from a retrospective assessment of 759,799 children from 103 Demographic and Health Surveys (DHS) across 56 countries during 2003–2020. Considering the month-long Ramadan exposure as a natural experiment, we implement an *intent-to-treat* framework, comparing stunting and underweight among children aged 0–5 years who were exposed to Ramadan fasting at any time *in utero* with those who were not exposed. Our findings do not show significant evidence to conclude that *in utero* exposure to the Ramadan fasting period is negatively associated with child nutrition. On the contrary, except for stunting in Muslim children who had *in utero* exposure to Ramadan fasting during the first months of pregnancy, we find no significant association between *in utero* exposure to Ramadan fasting and child stunting and underweight. Our main results are robust to multiple robustness checks.

Introduction

The practice of Ramadan is one of the five pillars of Islamic law, alongside pilgrimage and prayers, encompassing charity, and testimony of faith. During the holy month of Ramadan, Muslims abstain from food and drink from dawn to sunset. Despite the Quran exempting pregnant and lactating women from fasting, in most cultures, they prefer to fast. Previous research shows that between 70% and 90% of Muslim women, including pregnant mothers, participate in fasting for some days during the Ramadan month.[1–4] Thus, Ramadan fasting overlaps with pregnancy in three out of four births, which means that there are more than 1 billion Muslims alive today who had *in utero* exposure to Ramadan fasting.[5,6]

Nutrition and dietary behaviour during the *in utero* period have been critically linked to child health, physical growth, cognitive development and future abilities.[7] Known as the *foetal origins* hypothesis, undernutrition in the womb during the middle to late pregnancy stages has been linked to a wide range of adverse health outcomes.[7–9] Although metabolic penalties of fasting during Ramadan in pregnant and lactating women were observed in the mid to late 1980s,[10,11] evidence from studies over the past decade or so shows that maternal exposure to fasting during the Ramadan months has implications for child development.[5,6,12] Hence, fasting during pregnancy and its adverse effects on maternal and foetal health have been documented by existing literature.[4,6,12–14]

In contrast, an influential research work in the *Journal of Perinatology* of the *Nature* group by Kavehmanesh and Abolghasemi (2004) studied mothers who delivered in medical centres in Tehran and demonstrated that 'maternal fasting during Ramadan did not have a significant effect on the neonatal birth weight'.[15] Similarly, Petherick, Tuffnell and Wright (2014) studied pregnant Muslim women living in the UK who fasted during Ramadan and observed that fasting was not associated with adverse birth outcomes in their sample.[16] Other studies,[17–19] as well as two systematic reviews of the literature by Oosterwijk et al. (2021) and Glazier et al. (2018),[20,21] present a more neutral and inconclusive view on the relationship between *in utero* exposure to Ramadan fasting and health outcomes.

However, most previous studies have not investigated the role of potential changes in calorie intake and dietary diversity or quality among pregnant women exposed to Ramadan fasting compared with those who were not. Observing the eating practices during Ramadan, it is conceivable that despite the change in the timing of consumption, there may be no change in the total calorie consumption, dietary quality and dietary diversity. For instance, based on a prospective cohort study among schooling Ghanaian adolescents who fasted during Ramadan, Ali and Abizari (2018) reported that fasting made marked changes in typical food patterns and helped to improve dietary diversity.[22] Similarly, evidence from rural Bangladesh suggests that exposure to the Ramadan period helps to increase dietary quality in both fasting and non-fasting Muslim women.[1]

Although we do not have information on calorie consumption, dietary quality and dietary diversity from uniformly designed and linkable surveys across low-income and lower-middle-income countries to assess the effect of Ramadan fasting on food intake, it is possible to test the validity of the hypothesis that prenatal exposure to Ramadan fasting leads to poor child development across a large number of countries from diverse regions, cultures and food practices over time. Moreover, to the best of our knowledge, empirical evidence on the association between *in utero* exposure to Ramadan fasting and child development is from single-country studies, representing specific geographies and cultures with relatively small samples. Thus, there is a need to re-assess this relationship to determine whether the hypothesis holds in wider geographical and cultural contexts.

Against this backdrop, we aim to assess the links between *in utero* exposure to Ramadan fasting and child nutritional outcomes, using a sample of 759,799 children from 103 Demographic and Health Surveys (DHS) that were conducted in 56 countries during 2003–2020. Our paper contributes to the existing knowledge in several ways. First, previous studies on this topic relied on single-country studies with diverse conclusions across different geographical and cultural contexts. Our study, on the other hand, examines the association between *in utero* exposure to fasting and health outcomes from a large cohort of children, focusing on anthropometric outcomes of children aged under 5 years from diverse geographies, cultures and time points. Since there is no information in our dataset on whether a mother actually fasted, following previous studies,[6,12] we adopt an *intent-to-treat* framework, comparing outcomes among individuals who were exposed to Ramadan fasting at any time *in utero* (the treatment group) with those who were not exposed (the control group). Second, we adopt multiple robustness checks to verify the main findings. Third, our investigation contributes to the literature by examining the heterogeneity in the relationship between *in utero* exposure to Ramadan fasting and child nutritional outcomes at different stages of pregnancy from a relatively large sample.

Our findings suggest no clear association between *in utero* exposure to Ramadan fasting and child nutritional outcomes. At the outset, *in utero* exposure to Ramadan fasting is negatively associated with child nutrition, especially with the weight of children. However, this relationship varies across the different stages of pregnancy. We observe a positive relationship when exposure to Ramadan fasting occurs in the early months of pregnancy, turning into a negative relationship in the later months of pregnancy. Overall, there is no robust evidence that *in utero* exposure to Ramadan fasting is associated with child stunting and underweight.

Data and methods

Our study uses data from the DHS, a collection of nationally representative repeated cross-sectional surveys conducted in 90 developing countries since 1984. The DHS interviewed women of childbearing age (15–49 years) using a standard questionnaire across all countries and included detailed questions on the socio-economic and demographic characteristics of female respondents and their households, including information on education, marital status and religion. For the purposes of our study, we used information collected from the detailed birth history of all children born within 5 years prior to the survey, as well as the anthropometric measures for these children. Our final sample consists of more than 759,000 observations of children aged 0–5 years from 103 surveys conducted during the period 2003–2020 in 56 countries.

Selection of the sample for analysis

Figure 1 presents the detailed sample selection procedure for the construction of the estimation sample. Initially, we screened 110 surveys conducted in 62 countries that provide information on child stunting and underweight. We observed that 22 out of 62 countries provide no information on religion. Considering the religious composition of the general population, we noted that 12 countries are 100% non-Muslim (Armenia, Bolivia, Colombia, Dominican Republic, Guatemala, Honduras, Haiti, Peru, Myanmar, Namibia, Papua New Guinea and South Africa), while seven countries are predominantly Muslim (Jordan, Maldives, Niger, Pakistan, Tajikistan, Turkey and Yemen). Nevertheless, we excluded countries out of these seven countries because they had no information on our variables of interest. For example, Turkey and Colombia have no information on media access; Yemen has no information on mothers' education; and Kenya, Tanzania, and Eswatini provide no information on religion. One survey in Madagascar (2009) provided only information on stunting, not underweight.

To identify the child's potential *in utero* exposure to the Ramadan fasting period, we collected data on the occurrence of Ramadan from several sources. First, we collected information through the Umm al-Qura Calendar, which is a civil Islamic calendrical system used in Saudi Arabia.[1] Then we corroborated the records using online sources to make sure that the records were accurate. This data was linked to DHS data to identify whether a child had *in utero* exposure to the Ramadan month.

Dependent variables

Our dependent variables are the two standard anthropometric indicators of physical growth that describe child nutrition: a child's height-for-age (stunting) and weight-for-age (underweight). The DHS provides anthropometric information obtained by measuring children under 5 years of age and expressed as Z-scores in standard deviations from the median of the WHO's current Child Growth Standards reference population,[23] as described below:

The *height-for-age Z-score* (HAZ) measures the child's linear growth according to age. Children with a low height-for-age are said to be stunted. This indicator reflects the cumulative effects of growth deficiency and is used to measure long-term nutrition. It is associated with several factors, including chronic insufficient food intake, frequent infections, sustained incorrect feeding practices and low socio-economic family status.[24]

The *weight-for-age Z-score* (WAZ) measures the child's weight, again in standard deviations from the median of the reference population. Children with a low weight-for-age are said to be underweight. This indicator has been used to monitor the growth of children and is typically regarded as a measure of short-term nutrition. Socio-economic and environmental factors play a key role in explaining departures from optimal growth.[25,26]

[1]An Umm al-Qura Calendar converter for converting any date (1951–2100) from Gregorian to Hijri can be found from several online sources, such as https://webspace.science.uu.nl/~gent0113/islam/ummalqura_converter.htm

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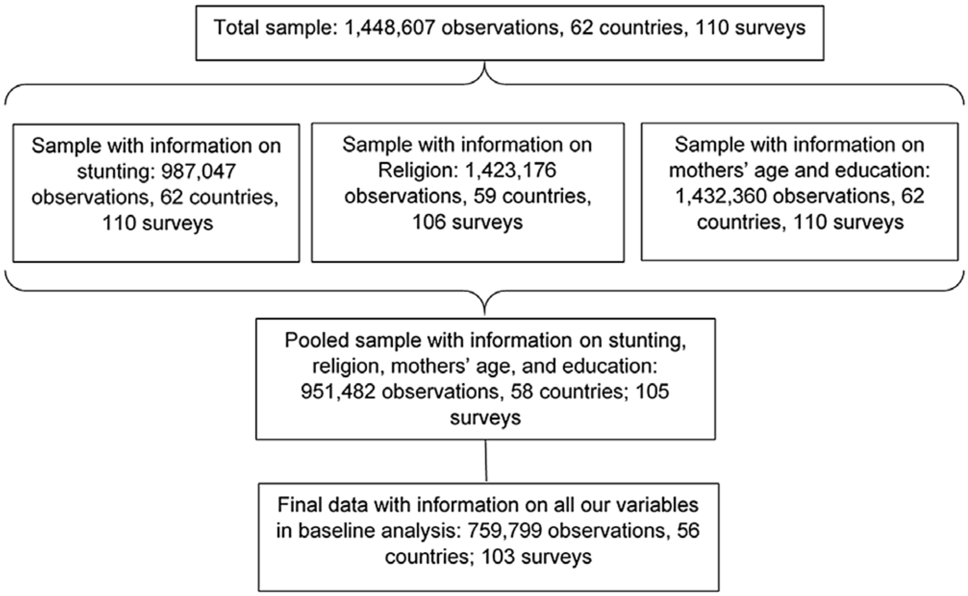

Figure 1. Sample selection procedure in the study.

Explanatory variables

In utero *exposure to the Ramadan fasting period*

The key explanatory variable in this study is a measure of *in utero* exposure to the Ramadan fasting period, defined as a binary variable, taking on a value of 1 if a child is exposed and 0 otherwise. To assign a child's *in utero* exposure to the Ramadan fasting period, we use the information on the month and year of the birth of the child. To construct the exposure variable, given that only information on the month of a child's birth is available for a significant proportion of the study sample, we assume two scenarios for those children whose months of birth were reported: (A) the first day of the month or (B) the last day of the month. Following Majid (2015) and Almond and Mazumder (2011),[5,6] we further assume that the pregnancy period lasts on average 266 days and identify the number of days the pregnancy period overlaps with the days of the Ramadan month. In both scenario A and scenario B, if the overlapping period is seven days or more, a child is coded as being exposed to the fasting month. By these assumptions, children born on any date of the known month of birth would have at least 7 days of overlap between pregnancy and Ramadan if they were classified as 'exposed'. A child will be categorised as not exposed if the overlapping time is zero. We excluded other observations, including children whose exposure period is 6 days or fewer and children about whom we are uncertain of whether they are exposed or not exposed.

Here, two points are worth noting. First, as pointed out earlier, even though pregnant Muslim women do not need to fast during the Ramadan month, about 70%–90% of Muslim women do so.[1–4] However, there is no information in our dataset on whether a mother actually fasted. Therefore, in keeping with the existing literature, such as Chaudhry and Mir (2021),[12] we adopt an *intent-to-treat* framework, comparing outcomes among individuals who were exposed to Ramadan fasting at any time *in utero* (the treatment group) with those who were not exposed (the control group).

Second, data on the exact date of birth of the child is available only in recent surveys (referred to as DHS-7).[2] To test the robustness of our results, we conduct a sub-sample analysis using this data. This includes a sample of around 157,000 children from 28 countries.

Third, although the Ramadan month potentially applies only to Muslim children, non-Muslims living in predominantly Muslim countries are reported to experience spillover effects through changes in access to services and work timings.[1,2,27] To account for this, we code two binary variables indicating whether a child's mother is Muslim (1) or not (0) and whether a child is exposed (1) or not (0); we run regressions on these variables and add an interaction term between these two variables.

Other control variables

We control for an array of child and household socio-economic and demographic characteristics. These include the child's gender and birth order, whether the child is part of single or multiple births, the mother's education, the mother's age and media accessibility. Additionally, we include household characteristics such as rural or urban residence, sex, age of the household head and household size. To account for a household's economic status, we use data on the wealth index available in the dataset, with which households are divided into five wealth quintiles ranging from the poorest to the richest.

Empirical analysis

We empirically estimate the association between *in utero* exposure to the Ramadan fasting period and two key child anthropometric measures. Given the binary nature of both our outcome variables, we estimate a probit estimation model. Specifically, we estimate the following equation:

[2]These surveys/years are as follows: Albania (2017), Armenia (2015), Angola (2015), Bangladesh (2017), Benin (2017), Burundi (2016), Cameroon (2018), Ethiopia (2008), Gambia (2019), Guinea (2018), Haiti (2016), Liberia (2019), Mali (2018), Myanmar (2015), Maldives (2015), Malawi (2015), Nigeria (2018), Nepal (2016), Papua New Guinea (2016), Pakistan (2017), Sierra Leon (2019), Senegal (2017, 2018, 2019), Tajikistan (2017), Timor-Leste (2016), Uganda (2016), South Africa (2016), Zambia (2018) and Zimbabwe (2015).

$$\text{Probit}\{P(Y_{j,c,t}=1)|\text{control}\} = \beta_0 + \beta_1\text{Muslim}_{j,c,t} + \beta_2\text{Exposure}_{j,c,t} + \beta_3\text{Muslim}_{j,c,t} * \text{Exposure}_{j,c,t} + \beta_j X_{j,c,t} + \theta_c + \mu_t + \varepsilon_{j,c,t} \quad (1)$$

where $Y_{j,c,y}$ is a binary variable indicating that a child j in country c and year t is stunted or underweight. *Muslim* is a dummy variable, taking on a value of 1 if the child's mother is Muslim and 0 otherwise. *Exposure* is a binary variable showing whether a child is exposed to the Ramadan month *in utero*. X is a vector of covariates that include the characteristics of the children, their mother and their household. We control for country fixed effects by adding the parameter θ_c and year fixed effects through parameter μ_t. The signs and significance of parameters β_1, β_2 and β_3 will indicate the difference in probability of a child being stunted or underweight relative to the base group: non-Muslim and non-exposed children. Also, since we control for country fixed effects (θ_c), the results compare children by their exposure status within a country. Stata software version MP 17.0 is employed for the statistical and empirical analysis.

Although the variable *Exposure* implies that the women fasted while pregnant, it is reasonable to assume that some of the women did not actually fast. If we assume that fasting potentially has an adverse influence on an outcome variable, then the magnitude of the effect of *Exposure* estimated from equation (1) should be lower than the true magnitude, since classifying women who did not fast as 'fasted' would have a neutralising effect on the outcome variable. Hence, while the true magnitude of the effect may not be precisely estimated, we are confident about the direction of the association, and we refer to the estimates from equation (1) as the lower bound of the potential association.

Results

Descriptive statistics

In our sample, Muslims account for 32.4% of the observations, and by our method of construction, 88.2% of Muslim children are expected to have been exposed to fasting *in utero* during Ramadan. Figure 2 shows the distribution of stunted and underweight children by religion and exposure status drawn from our full sample. Overall, Muslim children are less likely to be stunted and underweight compared with non-Muslim children. However, within Muslim children, we see slight differences in stunting and underweight by exposure status in favour of those who were exposed *in utero* to the Ramadan fasting month.

Table 1 provides the descriptive statistics of the main variables used in the empirical analysis. Of the full sample, approximately 51% of the children are male, and nearly all the children are part of a single birth (>97%). Regarding the mother's characteristics, there is a big difference in education between non-Muslim mothers and Muslim mothers. Around 49.3% of Muslim mothers have no education, compared with only around 25.5% of non-Muslim mothers. We observe a dominance of male-headed households in both non-Muslim (>82%) and Muslim (>85%) households. Rural residence is also similar, with a slightly higher rural residence among non-Muslim households (67.6%) than among Muslim households (around 67%). Muslim household size is on average larger than non-Muslim household size. In particular, the proportion of households having 6 or more members is around 66% in Muslim households, compared with 55% in non-Muslim households. Lastly, there are no significant differences in the distribution of the population by wealth index between non-Muslim and Muslim populations.

Regression results

The main results of the empirical analysis are presented in Tables 2 and 3, providing estimates of marginal effects with stunting and underweight being the outcome variables, respectively.

In utero exposure to Ramadan fasting and child stunting

Across all our models in Table 2, we found that relative to a non-Muslim child (non-exposed), a child from a household following the *Muslim* religion had a higher probability of being stunted. The variable *Exposure* is positive and statistically significant. Interestingly, the interaction term is negative and statistically significant in all regressions. In the full sample (Table 2, column 1), the estimate of the interaction term is negative (−0.014) and statistically significant at the 1% level, implying that compared with Muslim (non-exposed) children, a Muslim child who is exposed to Ramadan fasting *in utero* has a 1.4 percentage points lower probability of being stunted. This finding is robust to different sample settings, such as excluding American countries (column 2), using only African countries (column 3), excluding India (column 4) and using a sample of recent surveys only (column 5).

Exposure to Ramadan fasting and child underweight

Our results for child underweight (Table 3) are consistent with our findings for stunting. The probability of being underweight is higher among Muslim children than among non-Muslim children. However, among Muslim children, exposure to Ramadan fasting *in utero* is associated with being underweight. Specifically, in the full-sample results (column 1), the variable *Exposure* is positive but is not statistically significant. This supports our hypothesis that exposure to fasting does not significantly affect child nutrition for non-Muslim children. However, the interaction term (*Exposure to Ramadan*Muslim*) is negative and significant in all regressions. The estimates suggest that relative to non-exposed Muslim children, a Muslim child exposed to Ramadan fasting *in utero* has a 0.7–1.0 percentage points lower probability of being underweight. Hence, from both regressions of stunting and underweight, it is evident that exposure to Ramadan fasting *in utero* may not adversely affect child nutritional outcomes.

Apart from the main results, other results are consistent with what we would expect from the literature. In particular, we observe that better maternal education is associated with a lower stunting probability. For example, in the full-sample estimates, compared with a child with a mother who has no education, a child with a primary educated or at least secondary educated mother has a 2.3 or 8.3 (3.3 or 6.9) percentage points lower probability of being stunted (underweight), respectively. Similarly, a mother's experience (age) also helps alleviate child stunting and underweight. Compared with a child with a mother aged 15–19 years, a child whose mother is 20–29 years old has a 4.9 (3.0) percentage points lower probability of being stunted (underweight). The household head's experience also plays some role in reducing child stunting and underweight, since the variables associated with household head characteristics are negative and statistically significant. We also find that media access is important since the estimates are negative and statistically significant. Lastly, the probability of being

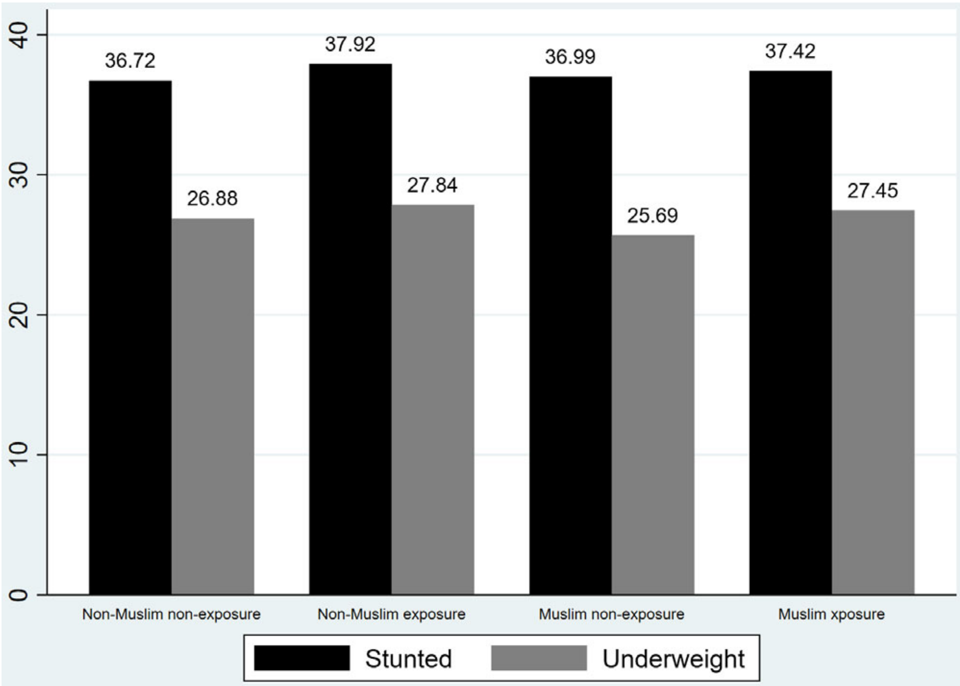

Figure 2. Level of stunted and underweight children (%) by Ramadan exposure status. *Source:* Author's self-calculation from the data sample using Stata software. The values are the weighted average over the full sample.

stunted or underweight decreases as a child moves to better-off quintiles of the wealth index.

Robustness checks

To test the robustness of our results, we conducted a series of robustness checks.

Sample of most recent-born children

The nutritional outcomes of children may be linked to other factors such as maternal utilisation of antenatal care. However, in the DHS surveys, female respondents were interviewed regarding the antenatal care of only their most recent-born children in the last 5 years before the survey. In this section, we present the regression results in which we additionally control for the following variables. First, we included a group of variables indicating (i) whether the mother received antenatal care from a medical professional, (ii) whether the mother made four antenatal care visits before birth and (iii) whether the child's birth was at an institution. Second, another group of dummy variables shows whether a mother's BMI (body mass index; normal is the base case) is underweight (1) or not (0), obese (1) or not (0), and not reported (1) or not (0). We also add two other control variables: whether the household uses flush toilets (1) or not (0) and piped water (1) or not (0). The sample size for this exercise is around 534,000 observations sourced from 100 surveys in 54 countries.

The estimation results presented in Table 4 show strong consistency with our findings in the previous section. In other words, non-exposed Muslim children are more likely to be stunted (Panel A) and underweight (Panel B) than non-Muslim children since the estimates for *Muslims* are positive and significant. Variable *Exposure* is positive but not significant in all the regressions of underweight, whereas the interaction term (*Muslims***Exposure*) is negative and significant in most of the regressions.

Controlling for country-level economic indicators

Table 5 reports the estimation results in which we additionally control for country-level economic characteristics. Specifically, we included the variables (log) Human Development Index (HDI), (log) GDP per head and (log) health expenditure per capita in the year of the child's birth, for the full sample and DHS-7 sample.[3]

The results (Panel A for stunting and Panel B for underweight) show that health expenditure is negatively associated with stunting, while a higher GDP per capita is associated with lower underweight prevalence. Apart from that, the findings for our main variables of interest in the full sample are similar to the baseline estimates presented in Tables 2 and 3. Overall, the results suggest that Muslim children are more likely to be stunted and underweight, but *in utero* exposure to Ramadan fasting has no negative influence on Muslim children.

Sample of Muslim children

In this section, we report results considering only the sample of Muslim children. Using equation (1), we directly estimate the relative difference in probability of being stunted or underweight for children with *in utero* exposure to the Ramadan fasting month, compared with those who were not exposed to Ramadan fasting *in utero*. The results presented in Table 6, Panel A, show that the estimate for the *Exposure* variable is negative and statistically significant in three out of four models, corresponding to different samples. Similarly, the results in Panel B for underweight show that *Exposure* is negative and statistically significant in all models, suggesting that exposed children are roughly 1.0 percentage point less likely to be underweight than non-exposed children. These results once again emphasise that relative to other socio-economic factors,

[3]HDI is sourced from UNDP (http://hdr.undp.org/en/content/download-data). GDP per capita is PPP (2017 constant international $), and health expenditure per capita is domestic general government health expenditure (PPP current international $), which are both sourced from the World Development Indicators database (The World Bank).

Table 1. Descriptive statistics of variables

Variables	Non-Muslim (%)	Muslim & non-exposure (%)	Muslim & exposure (%)
Dependent variables			
Child is stunted	35.45 (0.09)	33.11 (0.28)	32.51 (0.1)
Child is underweight	22.75 (0.08)	22.63 (0.25)	22.61 (0.09)
Explanatory variables			
Child is male	50.97 (0.09)	51.12 (0.3)	50.73 (0.11)
Child is a part of a single birth	97.87 (0.03)	97.29 (0.1)	97.46 (0.03)
Birth order of child: 1st	29.94 (0.09)	24.36 (0.25)	24.33 (0.09)
Birth order of child: 2nd	25.5 (0.08)	21.35 (0.24)	21.91 (0.09)
Birth order of child: 3rd+	44.56 (0.09)	54.28 (0.3)	53.77 (0.11)
Mother has no education	25.52 (0.08)	49.35 (0.3)	49.31 (0.11)
Mother has primary education	31.16 (0.08)	17.31 (0.22)	17.83 (0.08)
Mother has secondary or higher education	43.32 (0.09)	33.34 (0.28)	32.85 (0.1)
Mother's age: 15–19	4.85 (0.04)	5.29 (0.13)	5.4 (0.05)
Mother's age: 20–29	57.64 (0.09)	53.52 (0.3)	54.08 (0.11)
Mother's age: 30+	37.51 (0.09)	41.19 (0.29)	40.53 (0.11)
Household head is male	82.15 (0.07)	86.2 (0.2)	85.94 (0.08)
Age of household head: 13–29	20.27 (0.07)	13.3 (0.2)	13.64 (0.07)
Age of household head: 30–59	65.32 (0.09)	69.54 (0.27)	68.92 (0.1)
Age of household head: 60+	14.4 (0.06)	17.16 (0.22)	17.44 (0.08)
Household size: 1–3 persons	9.5 (0.06)	6.59 (0.15)	6.74 (0.05)
Household size: 4–5 persons	35.67 (0.09)	27.31 (0.26)	27.27 (0.1)
Household size: 6+ persons	54.83 (0.09)	66.1 (0.28)	65.99 (0.1)
Access to media	75.93 (0.07)	73.31 (0.26)	74.17 (0.09)
Household is in rural area	67.6 (0.09)	67.6 (0.28)	66.92 (0.1)
Wealth Index: 1st quintile	23.43 (0.07)	23.01 (0.25)	23.18 (0.09)
Wealth Index: 2nd quintile	21.76 (0.07)	22.45 (0.25)	21.75 (0.09)
Wealth Index: 3rd quintile	20.27 (0.07)	20.22 (0.24)	20.4 (0.09)
Wealth Index: 4th quintile	18.57 (0.07)	18.87 (0.23)	19.17 (0.09)
Wealth Index: 5th quintile	15.97 (0.07)	15.44 (0.21)	15.5 (0.08)
No. of observations	513,330	29,025	217,444

Note: We report the proportion of children by background characteristics of their mothers and households; standard errors are in brackets.

exposure to the Ramadan fasting month may not have a net adverse impact on child nutrition.

Heterogeneity of exposure effects

Previous research has shown that the potential impacts on child health due to *in utero* exposure to the Ramadan fasting month will likely depend on the timing of the exposure.[12] Prior to that, Awwad et al. (2012),[28] based on their prospective study, found that gestational age may not influence the relationship between Ramadan fasting and maternal health. Considering these contradicting findings from local-level micro-studies, we assessed whether the timing of Ramadan exposure during pregnancy matters for health outcomes using a relatively large geographically dispersed sample. Below we provide estimates of marginal effects drawn from the sample of Muslim children, where we take into account the timing of the *in utero* exposure.

The existing literature from a country-specific perspective suggests that *in utero* exposure to Ramadan fasting in the early stages of gestation has strong negative effects on the health outcomes of children.[12] In light of this, we design another sub-sample of Muslim children, taken only from recent surveys, for whom we have precise information on the child's date of birth. Next, we estimate the heterogeneous effects of exposure by month of gestation.

Consistent with the literature, our results in Table 7 show that exposure to Ramadan fasting up to the 3rd month of gestation is positively associated with child stunting. Compared with a non-exposed child, a child would be 2.1, 2.3, 1.4 and 2.1 percentage points more likely to be stunted if his/her mother was exposed to the Ramadan month during conception and in the 1st month, 2nd month, or 3rd month of pregnancy, respectively (column 1). The results controlled for the level of HDI (column 3), GDP per capita (column 4), or health expenditure per capita (column 5)

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Table 2. Estimates of marginal effects of exposure to Ramadan fasting period on child stunting

	(1) Global	(2) Excl. Americas	(3) Africa	(4) Excl. India	(5) DHS-7
Muslim	0.031*** (0.004)	0.032*** (0.004)	0.050*** (0.005)	0.037*** (0.004)	0.031*** (0.007)
Exposure	0.004** (0.002)	0.005** (0.002)	0.010*** (0.003)	0.006*** (0.002)	0.008** (0.004)
Muslim* Exposure	−0.014*** (0.004)	−0.014*** (0.004)	−0.019*** (0.005)	−0.012*** (0.004)	−0.011* (0.006)
Child is male	0.035*** (0.001)	0.035*** (0.001)	0.049*** (0.001)	0.041*** (0.001)	0.040*** (0.002)
Child's age (months)	0.018*** (0.000)	0.018*** (0.000)	0.020*** (0.000)	0.018*** (0.000)	0.017*** (0.000)
Child's age (months) squared	−0.000*** (0.000)	−0.000*** (0.000)	−0.000*** (0.000)	−0.000*** (0.000)	−0.000*** (0.000)
Child's birth order: 1st birth (ref.)					
Child's birth order: 2nd birth	0.014*** (0.002)	0.012*** (0.002)	−0.003 (0.002)	0.008*** (0.002)	0.006* (0.003)
Child's birth order: 3rd birth	0.035*** (0.002)	0.030*** (0.002)	0.011*** (0.003)	0.028*** (0.002)	0.015*** (0.004)
Child is part of a multiple birth (ref.)					
Child is part of a single birth	−0.134*** (0.004)	−0.137*** (0.004)	−0.158*** (0.005)	−0.141*** (0.004)	−0.165*** (0.008)
Mother's education: no education (ref)					
Primary education	−0.023*** (0.002)	−0.029*** (0.002)	−0.027*** (0.002)	−0.022*** (0.002)	−0.034*** (0.003)
Secondary education +	−0.083*** (0.002)	−0.080*** (0.002)	−0.076*** (0.003)	−0.085*** (0.002)	−0.076*** (0.004)
Mother's age: 15–19 (ref.)					
Mother's age: 20–29	−0.049*** (0.003)	−0.050*** (0.003)	−0.046*** (0.004)	−0.048*** (0.003)	−0.051*** (0.005)
Mother's age: 30+	−0.078*** (0.003)	−0.079*** (0.003)	−0.073*** (0.004)	−0.074*** (0.003)	−0.080*** (0.006)
Household size: 6+ persons (ref.)					
Household Size: 1–3 persons	−0.027*** (0.002)	−0.017*** (0.002)	−0.007** (0.003)	−0.024*** (0.002)	−0.020*** (0.005)
Household Size: 4–5 persons	−0.020*** (0.001)	−0.015*** (0.001)	−0.008*** (0.002)	−0.017*** (0.001)	−0.018*** (0.003)
Household head is male	0.002 (0.002)	0.001 (0.002)	0.006*** (0.002)	0.004** (0.002)	0.006** (0.003)
Household head's age: 13–29 (ref.)					
Household head's age: 30–59	−0.019*** (0.002)	−0.018*** (0.002)	−0.011*** (0.002)	−0.016*** (0.002)	−0.015*** (0.004)
Household head's age: 60+	−0.026*** (0.002)	−0.024*** (0.002)	−0.012*** (0.003)	−0.021*** (0.003)	−0.016*** (0.005)
Exposed to media (TV, newspaper, radio)	−0.016*** (0.002)	−0.022*** (0.002)	−0.021*** (0.002)	−0.014*** (0.002)	−0.019*** (0.003)
Rural household	0.011*** (0.002)	0.004** (0.002)	0.017*** (0.003)	0.020*** (0.002)	0.003 (0.004)
Household wealth quintile: Poorest (ref.)					
Poorer	−0.038*** (0.002)	−0.029*** (0.002)	−0.020*** (0.002)	−0.037*** (0.002)	−0.026*** (0.004)
Middle	−0.077*** (0.002)	−0.063*** (0.002)	−0.049*** (0.003)	−0.073*** (0.002)	−0.063*** (0.004)
Richer	−0.117*** (0.002)	−0.104*** (0.002)	−0.083*** (0.003)	−0.106*** (0.002)	−0.101*** (0.004)
Richest	−0.183*** (0.003)	−0.176*** (0.003)	−0.155*** (0.004)	−0.169*** (0.003)	−0.170*** (0.005)
Country dummies	Yes	Yes	Yes	Yes	Yes
Survey year dummies	Yes	Yes	Yes	Yes	Yes
N	759,799	671,606	365,967	549,856	157,440

Notes: The table reports marginal effects with robust standard errors in parentheses. ***, ** and * report statistical significance at 1%, 5% and 10%, respectively. The first column reports full-sample results; South American countries are excluded in column 2; column 3 reports estimates for African countries; column 4 excludes India; and column 5 limits the sample to recent surveys (referred to as DHS-7). For child's age squared, the estimates are statistically significant, but numerically their meaning is so small that they can be ignored; hence the rounded value is 0.000.

are more or less the same. When the sample is limited to most recent births (column 2), the influence of exposure in the 2nd and 3rd months disappears. From months 4 to 6 of the gestation period, the pattern of influence of exposure reverses, and the results are consistent in all five specifications. Compared with non-exposed children, the strongest positive association is found for children in the 4th month of *in utero* exposure, who are 1.9–2.2 percentage points less likely to be stunted; exposure in the 5th and 6th months is associated with an around 1.3 percentage points lower probability of being stunted. Lastly, exposure during the 7th to 9th months of pregnancy (born in the month of Ramadan) is not associated with a higher probability of being stunted.

With regard to underweight (Table 8), we do not observe a clear pattern of association between Ramadan exposure in the first three months of pregnancy and child underweight. The strongest negative correlation is found for exposure during the conception period

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Table 3. Estimates of marginal effects of exposure to Ramadan fasting period on child underweight

	(1) Global	(2) Excl. Americas	(3) Africa	(4) Excl. India	(6) DHS-7
Muslim	0.024*** (0.003)	0.026*** (0.004)	0.050*** (0.004)	0.043*** (0.003)	0.035*** (0.006)
Exposure	−0.001 (0.002)	−0.001 (0.002)	−0.000 (0.003)	−0.000 (0.002)	−0.000 (0.003)
Muslim* Exposure	−0.009*** (0.003)	−0.009*** (0.003)	−0.009** (0.004)	−0.007** (0.003)	−0.010** (0.005)
Child is male	0.018*** (0.001)	0.019*** (0.001)	0.026*** (0.001)	0.019*** (0.001)	0.019*** (0.002)
Child's age	0.005*** (0.000)	0.006*** (0.000)	0.006*** (0.000)	0.005*** (0.000)	0.005*** (0.000)
Child's age squared	−0.000*** (0.000)	−0.000*** (0.000)	−0.000*** (0.000)	−0.000*** (0.000)	−0.000*** (0.000)
Child's birth order: 1st birth (ref.)					
Child's birth order: 2nd birth	0.007*** (0.001)	0.007*** (0.001)	−0.001 (0.002)	0.002 (0.002)	0.002 (0.003)
Child's birth order: 3rd birth	0.018*** (0.001)	0.018*** (0.002)	0.004* (0.002)	0.010*** (0.002)	0.007** (0.003)
Child is part of a multiple birth (ref.)					
Child is part of a single birth	−0.117*** (0.003)	−0.124*** (0.004)	−0.120*** (0.004)	−0.109*** (0.003)	−0.120*** (0.006)
Mother's education: no education (ref)					
Primary education	−0.033*** (0.001)	−0.036*** (0.002)	−0.033*** (0.002)	−0.029*** (0.002)	−0.028*** (0.003)
Secondary education +	−0.069*** (0.002)	−0.073*** (0.002)	−0.063*** (0.002)	−0.062*** (0.002)	−0.051*** (0.003)
Mother's age: 15–19 (ref.)					
Mother's age: 20–29	−0.030*** (0.002)	−0.034*** (0.003)	−0.031*** (0.003)	−0.027*** (0.002)	−0.026*** (0.005)
Mother's age: 30+	−0.049*** (0.003)	−0.056*** (0.003)	−0.041*** (0.003)	−0.036*** (0.003)	−0.036*** (0.005)
Household size: 6+ persons (ref.)					
Household Size: 1–3 persons	−0.014*** (0.002)	−0.013*** (0.002)	−0.006** (0.003)	−0.008*** (0.002)	−0.012*** (0.004)
Household Size: 4–5 persons	−0.012*** (0.001)	−0.012*** (0.001)	−0.008*** (0.002)	−0.009*** (0.001)	−0.014*** (0.003)
Household head is male	0.002 (0.001)	0.002 (0.002)	0.001 (0.002)	0.001 (0.001)	0.003 (0.003)
Household head's age: 13–29 (ref.)					
Household head's age: 30–59	−0.007*** (0.001)	−0.008*** (0.002)	−0.002 (0.002)	−0.003 (0.002)	−0.007** (0.003)
Household head's age: 60+	−0.013*** (0.002)	−0.015*** (0.002)	−0.004 (0.003)	−0.006*** (0.002)	−0.008** (0.004)
Exposed to media (TV, newspaper, radio)	−0.019*** (0.001)	−0.022*** (0.001)	−0.022*** (0.002)	−0.018*** (0.001)	−0.020*** (0.002)
Rural household	−0.004*** (0.001)	−0.006*** (0.002)	0.003 (0.002)	0.003* (0.002)	−0.001 (0.003)
Household wealth quintile: Poorest (ref.)					
Poorer	−0.035*** (0.001)	−0.035*** (0.002)	−0.023*** (0.002)	−0.026*** (0.002)	−0.024*** (0.003)
Middle	−0.063*** (0.002)	−0.063*** (0.002)	−0.043*** (0.002)	−0.046*** (0.002)	−0.048*** (0.003)
Richer	−0.089*** (0.002)	−0.092*** (0.002)	−0.065*** (0.002)	−0.065*** (0.002)	−0.066*** (0.004)
Richest	−0.139*** (0.002)	−0.146*** (0.002)	−0.107*** (0.003)	−0.104*** (0.002)	−0.104*** (0.005)
Country dummies	Yes	Yes	Yes	Yes	Yes
Survey year dummies	Yes	Yes	Yes	Yes	Yes
N	755,506	667,317	361,832	545,563	157,148

Notes: The table reports marginal effects with standard errors in parentheses. ***, ** and * report statistical significance at 1%, 5% and 10%, respectively. The first column reports full-sample results; South American countries are excluded in column 2; column 3 reports estimates for African countries; column 4 excludes India; and column 5 limits the sample to recent surveys (referred to as DHS-7).

(a roughly 1.3 percentage points higher probability of being underweight if the starting day of conception fell in the month of Ramadan). Estimates for exposure in months 4–9 are negative and statistically significant, which suggests that the probability of being underweight is lower for exposed children than for non-exposed children.

These results still hold in a sample of recent-born children (column 2) and when we control for country-level macro-level development indicators, such as the HDI, GDP per capita, or health expenditure per capita (columns 3–5). From column 1, we observe that the probability of a child being underweight is 1.8, 1.1, 1.0 1,7, 1.5 and 1.5 percentage points lower if his/her mother was exposed

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Table 4. Estimates of marginal effects of exposure to Ramadan on child stunting and underweight – sample of most recent-born children

	(1) Global	(2) Excl. Americas	(3) Africa	(4) Excl. India	(5) DHS-7
	Panel A – Outcome variable: Stunting				
Muslim	0.035*** (0.004)	0.036*** (0.004)	0.049*** (0.006)	0.037*** (0.005)	0.031*** (0.007)
Exposure	0.005** (0.002)	0.005** (0.003)	0.010*** (0.004)	0.006** (0.003)	0.005 (0.005)
Muslim* Exposure	−0.015*** (0.004)	−0.015*** (0.004)	−0.019*** (0.005)	−0.012*** (0.004)	−0.006 (0.007)
N	534,864	469,976	254,974	380,197	109,715
	Panel A – Outcome variable: Underweight				
Muslim	0.026*** (0.004)	0.028*** (0.004)	0.041*** (0.005)	0.035*** (0.004)	0.032*** (0.006)
Exposure	0.001 (0.002)	0.002 (0.002)	0.002 (0.003)	0.001 (0.002)	0.002 (0.004)
Muslim* Exposure	−0.011*** (0.004)	−0.012*** (0.004)	−0.009** (0.004)	−0.008** (0.004)	−0.010* (0.006)
N	531,898	467,012	252,132	377,231	109,496

Note: All models controlled for child age, birth order, single or multiple births, mothers age, household size, household head age, mass media expsoure, wealth status, country and time dummies and additionally also controlled for antenatal care, the mother's BMI, and the household using a flush toilet and piped water.

Table 5. Estimates of marginal effects of exposure to Ramadan fasting on child stunting and underweight – additional controls

	(1) Full	(2) DHS-7	(3) Full	(4) DHS-7	(5) Full	(6) DHS-7
	Panel A – Outcome variable: Stunting					
Muslim	0.031*** (0.004)	0.031*** (0.007)	0.031*** (0.004)	0.032*** (0.007)	0.030*** (0.004)	0.031*** (0.007)
Exposure	0.005** (0.002)	0.008* (0.004)	0.004** (0.002)	0.008* (0.004)	0.005** (0.002)	0.007* (0.004)
Muslim* Exposure	−0.013*** (0.004)	−0.011* (0.006)	−0.014*** (0.004)	−0.011* (0.006)	−0.013*** (0.004)	−0.011* (0.006)
HDI	0.076** (0.034)	−0.073 (0.067)				
GDP per head			0.025*** (0.009)	0.033 (0.028)		
HXPDPCAP					−0.009*** (0.003)	−0.012** (0.006)
N	757,386	157,321	759,680	157,321	749,090	154,689
	Panel B – Outcome variable: Underweight					
Muslim	0.024*** (0.003)	0.035*** (0.006)	0.024*** (0.003)	0.035*** (0.006)	0.024*** (0.003)	0.037*** (0.005)
Exposure	0.001 (0.002)	0.000 (0.003)	0.001 (0.002)	0.000 (0.003)	0.001 (0.002)	0.000 (0.004)
Muslim* Exposure	−0.009*** (0.003)	−0.010** (0.005)	−0.009*** (0.003)	−0.011** (0.005)	−0.009*** (0.003)	−0.012** (0.005)
HDI	−0.005 (0.030)	−0.04 (0.055)				
GDP per head			−0.014* (0.008)	−0.096*** (0.022)		
HXPDPCAP					−0.003 (0.002)	−0.004 (0.004)
N	753,093	157,029	755,387	157,029	744,798	154,398

Note: All models include controls for child age, birth order, single or multiple births, mothers age, household size, household head age, mass media expsoure, wealth status, country and time dummies.

to the Ramadan fasting month during the 4th to 9th months of gestation, respectively.

Weighted regressions

So far, we have presented findings and drawn general conclusions based on unweighted regression estimations. Since we analyse a sample of individuals pooled from nationally representative surveys of multiple countries and aim to provide a global view, country weighting may need to be taken into account. Nevertheless, sample weights are available only within each national survey. Therefore, we construct a country weight, as follows:

$$CW = W\frac{P}{S}$$

where CW is the country weight, W is the sample weight that is already available in the DHS data, P refers to the estimated population of women aged 15–49 in the survey year (sourced from World Population Prospects 2019 – United Nations), and S is the sample size in the DHS surveys of the corresponding country and survey years. This measure of country weight implies that countries with larger populations of women aged 15–49 will have more influence on the estimates.

Table 6. Estimates of marginal effects of exposure to Ramadan fasting period on child stunting and underweight – sample of Muslim population

	(1) Full	(2) Africa	(3) Excl. India	(4) DHS-7
Panel A – Outcome variable: Stunting				
Exposure	−0.009*** (0.003)	−0.010*** (0.004)	−0.006** (0.003)	−0.002 (0.004)
N	246,467	159,372	213,442	69,753
Panel B – Outcome variable: Underweight				
Exposure	−0.010*** (0.003)	−0.011*** (0.003)	−0.009*** (0.003)	−0.010*** (0.004)
N	246,371	159,295	213,346	69,688

Note: All models include controls for child age, birth order, single or multiple births, mothers age, household size, household head age, mass media expsoure, wealth status, country and time dummies.

Table 7. Estimates of marginal effects of exposure to the Ramadan fasting period on child stunting by month of exposure

Variable	(1) Global	(2) Most recent-born	(3) Control HDI	(4) Control GDPPCAP	(5) Control HXPDPCAP
Month_0	0.021*** (0.007)	0.017** (0.009)	0.022*** (0.007)	0.021*** (0.007)	0.021*** (0.007)
Month_1	0.023*** (0.007)	0.019** (0.008)	0.024*** (0.007)	0.023*** (0.007)	0.022*** (0.007)
Month_2	0.014** (0.007)	0.000 (0.008)	0.016** (0.007)	0.014** (0.007)	0.015** (0.007)
Month_3	0.021*** (0.007)	0.008 (0.008)	0.021*** (0.007)	0.021*** (0.007)	0.021*** (0.007)
Month_4	−0.022*** (0.007)	−0.019** (0.008)	−0.023*** (0.007)	−0.022*** (0.007)	−0.020*** (0.007)
Month_5	−0.013* (0.007)	−0.011 (0.008)	−0.013** (0.007)	−0.013* (0.007)	−0.012* (0.007)
Month_6	−0.013* (0.007)	−0.010 (0.008)	−0.014** (0.007)	−0.013* (0.007)	−0.013* (0.007)
Month_7	−0.005 (0.007)	0.002 (0.008)	−0.006 (0.007)	−0.005 (0.007)	−0.005 (0.007)
Month_8	−0.002 (0.007)	−0.000 (0.008)	−0.003 (0.007)	−0.002 (0.007)	−0.002 (0.007)
Month_9	−0.001 (0.007)	−0.001 (0.008)	−0.001 (0.007)	−0.001 (0.007)	−0.000 (0.007)
HDI			−0.504*** (0.105)		
GDP per head				0.011 (0.044)	
HXPDPCAP					0.020* (0.011)
N	69,753	46,984	69,644	69,644	67,611

Notes: In Table 4 (2) and (4), *Month_0* is a binary variable indicating whether a child was exposed to Ramadan fasting during conception (1) or not (0). *Month_j* indicates whether a child was exposed during month *j* of the pregnancy period (1) or not (0), and *Month_9* indicates whether a child was born in the month of Ramadan (1) or not (0). All models include controls for child age, birth order, single or multiple births, mothers age, household size, household head age, mass media expsoure, wealth status, country and time dummies.

Tables A1–A4 provide estimates using sample weights. The estimates and levels of significance of the main variables change; however, our general findings from the weighted regression estimations still hold. That is, *in utero* exposure to the Ramadan fasting month is not associated with higher child stunting and underweight.

Discussion

Our analysis using an *intent-to-treat* framework comparing nutritional outcomes among children who were exposed to the Ramadan fasting period any time *in utero* with those who were not exposed finds no negative influence of exposure to the Ramadan fasting period on child nutritional outcomes. Thus, our findings fail to support the hypothesis that exposure to the Ramadan fasting period is negatively associated with child nutritional outcomes. These findings are robust to sub-sample analyses by religion, regions and timing of exposure after controlling for several socio-economic, demographic and maternal healthcare variables. The only exception is exposure during the early months of pregnancy, where we observe a slightly negative influence on child linear growth but not on underweight. Our results contrast with a few country specific studies.[5–9,12] However, our results are in tune with many other population-based and hospital-based cohart studies and also with the conclusions of two systematic reviews of the global literature by Oosterwijk et al. (2021) and Glazier et al. (2018).[15–21]

Nonetheless, we failed to link changes in dietary practices during Ramadan to child nutrition. The information on dietary behaviours of respondents was not available in the DHS, making it difficult to classify with complete certainty whether and how frequently or strictly fasting was undertaken by pregnant women, and to account for the change in quantity and nutritional diversity of their food consumption during the fasting month.

A hypothesis espoused by previous micro-studies that documented dietary and lifestyle practices during Ramadan fasting

Table 8. Estimates of marginal effects of exposure to Ramadan fasting period on child underweight by month of exposure

Variable	(1) Global	(2) Most recent-born	(3) Control HDI	(4) Control GDP	(5) Control HXPDPCAP
Month_0	0.012** (0.006)	0.014* (0.008)	0.013** (0.006)	0.014** (0.006)	0.012* (0.006)
Month_1	0.002 (0.006)	0.003 (0.007)	0.005 (0.006)	0.005 (0.006)	0.001 (0.006)
Month_2	0.005 (0.006)	−0.001 (0.007)	0.008 (0.006)	0.007 (0.006)	0.004 (0.006)
Month_3	−0.005 (0.006)	−0.013* (0.007)	−0.004 (0.006)	−0.005 (0.006)	−0.006 (0.006)
Month_4	−0.018*** (0.006)	−0.011 (0.007)	−0.019*** (0.006)	−0.020*** (0.006)	−0.017*** (0.006)
Month_5	−0.011* (0.006)	−0.010 (0.007)	−0.012** (0.006)	−0.012** (0.006)	−0.011* (0.006)
Month_6	−0.010* (0.006)	−0.007 (0.007)	−0.011* (0.006)	−0.012** (0.006)	−0.010* (0.006)
Month_7	−0.017*** (0.006)	−0.014** (0.007)	−0.018*** (0.006)	−0.018*** (0.006)	−0.018*** (0.006)
Month_8	−0.015** (0.006)	−0.013* (0.007)	−0.016*** (0.006)	−0.016*** (0.006)	−0.016*** (0.006)
Month_9	−0.015** (0.006)	−0.015** (0.007)	−0.016*** (0.006)	−0.016** (0.006)	−0.016** (0.006)
HDI			−0.725*** (0.090)		
GDP per head				−0.230*** (0.038)	
HXPDPCAP					0.043*** (0.009)
N	69,688	46,928	69,579	69,579	67,546

Note: All models include control for child age, birth order, single or multiple births, mothers age, household size, household head age, mass media expsoure, wealth status, country and time dummies.

may help in explaining our results. Ramadan encourages a healthy lifestyle, and Muslim people tend to have a better and more diverse diet during the Ramadan fasting month, despite the fact that eating and drinking happens only before sunrise and after sunset.[1,22,29] Usually, households tend to spend more financial resources during the festive seasons. A more recent report points out that even though Ramadan is a fasting month, food intake during the time of *Iftar* to *Suhoor* is higher than normal. Specifically, the consumption of fruits, high-nutrient nuts, dairy products and meat increases significantly during Ramadan. Furthermore, the reduced working hours during the Ramadan fasting month also lessens the overall energy requirements. The report further notes that 'not only food bills increase by 50%–100% during Ramadan, but it is reported that 83% of families change their food consumption habits during Ramadan. It is estimated that food consumption in Ramadan accounts for 15% of annual expenditure on food'.[27]

Previous research from Indonesia also supports this. Muslim wage earners receive a bonus (known as *Tunjangan Hari Raya*, or *THR*) from their employers before the Ramadan month. This bonus can be used to finance better food consumption during the month. The tradition of *Zakat* or giving to charity generates more financial resources for marginalised Muslim people, so during the Ramadan month, the distribution of food consumption temporarily improves among poor households. This in turn may improve diets during the Ramadan months. Extending this hypothesis further, Kunto and Mandemarkers (2019) found that exposure to Ramadan fasting exerted positive effects on the height of less religious Muslim children aged 10–14 and negative effects on that of non-Muslim children aged 0–4 in Indonesia.[2] The authors then speculate on the possible impact of *THR* and *Zakat* as an explanation for their findings.

Previous research that shows a Muslim advantage in child nutrition and child survival in South Asia attributes it to better handwashing and hygienic practices among Muslims, especially before prayers.[30] Although it is well known that the number of times Muslims pray during the holy month of Ramadan is higher than on normal days, they also keep their surroundings relatively cleaner and more hygienic during the Ramadan month compared with normal months. This may cause relatively healthier maternal lifestyles and hygienic practices during Ramadan, which in turn may potentially help achieve better pregnancy outcomes and child health.

Conclusion

To sum up, this study provides critical empirical evidence to advance the discussion around a long-standing debate on the possible link between *in utero* exposure to Ramadan fasting and child nutritional outcomes. Future research on this question should focus more on the potential mechanisms, including changes in hygienic, social interaction, and charity and dietary practices attached to the culture of Ramadan. Our study found that that the mere exposure to Ramadan fasting is not detrimental to child health outcomes.

Our general findings and conclusions have some limitations. First, since our data do not allow us to identify who actually fasted and the exact number of days the women fasted during the Ramadan month while pregnant, our empirical estimates might not reflect the true effects. Second, this study investigates only child stunting and underweight. Other measures of health outcome, which may be affected by exposure *in utero* to the fasting month regardless of the direction of the effects, are not available within our data sample. Thus, our overall conclusions are based on examining only child stunting and underweight.

Availability of data and materials. The datasets used and/or analysed during the current study are available from Demographic and Health Surveys. All the data is publicly accessible at https://dhsprogram.com/data/available-datasets.cfm.

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Conflicts of interest. None.

Ethical standards. This study used publicly available secondary sources of data, and thus did not require ethical approval.

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Appendix A: Weight regression

Table A1. Estimates of marginal effects of exposure to Ramadan fasting period on stunting- Weighted regressions

	(1) Global	(2) Excl. Americas	(3) Africa	(4) Excl. India	(5) DHS-7
			Panel A		
Muslim	0.033*** (0.007)	0.035*** (0.007)	0.067*** (0.009)	0.038*** (0.008)	0.023* (0.013)
Exposure	0.007* (0.004)	0.008* (0.004)	−0.003 (0.005)	−0.002 (0.004)	−0.003 (0.008)
Muslim* Exposure	−0.009 (0.007)	−0.010 (0.007)	−0.013* (0.008)	0.004 (0.007)	0.008 (0.011)
			Panel B (Most recent-born child)		
Muslim	0.038*** (0.008)	0.040*** (0.008)	0.064*** (0.009)	0.037*** (0.009)	0.024* (0.014)
Exposure	0.009* (0.005)	0.010** (0.005)	−0.000 (0.006)	−0.001 (0.005)	−0.004 (0.009)
Muslim* Exposure	−0.015* (0.008)	−0.017** (0.008)	−0.018** (0.009)	0.000 (0.008)	0.012 (0.014)
			Panel C (controlled for country-wide HDI, GDP per capita, health expenditure per capita)		
Muslim	0.034*** (0.007)	0.024* (0.013)	0.033*** (0.007)	0.023* (0.013)	0.034*** (0.007)
Exposure	0.008** (0.004)	−0.002 (0.008)	0.007* (0.004)	−0.002 (0.008)	0.008** (0.004)
Muslim* Exposure	−0.010 (0.007)	0.007 (0.011)	−0.009 (0.007)	0.007 (0.011)	−0.010 (0.007)
			Panel D (Muslim population only)		
Exposure	−0.002 (0.005)	−0.002 (0.005)	−0.017*** (0.006)	0.002 (0.006)	0.007 (0.009)

Table A2. Estimates of marginal effects of exposure to Ramadan fasting period on underweight- Weighted regressions

	(1) Global	(2) Excl. Americas	(3) Africa	(4) Excl. India	(5) DHS-7
			Panel A		
Muslim	0.016** (0.007)	0.017** (0.007)	0.058*** (0.007)	0.040*** (0.007)	0.032*** (0.011)
Exposure	−0.001 (0.004)	−0.001 (0.004)	−0.006 (0.005)	−0.005 (0.004)	−0.001 (0.007)
Muslim* Exposure	0.001 (0.006)	0.001 (0.007)	−0.004 (0.006)	0.007 (0.006)	−0.004 (0.010)
			Panel B (Most recent-born child)		
Muslim	0.015** (0.008)	0.016** (0.008)	0.045*** (0.008)	0.027*** (0.008)	0.018 (0.012)
Exposure	0.000 (0.004)	0.001 (0.005)	−0.004 (0.005)	−0.005 (0.005)	−0.003 (0.008)
Muslim* Exposure	−0.002 (0.007)	−0.003 (0.008)	−0.004 (0.007)	0.006 (0.007)	0.005 (0.012)
			Panel C (controlled for country-wide HDI, GDP per capita, health expenditure per capita)		
Muslim	0.016** (0.007)	0.034*** (0.011)	0.016** (0.007)	0.034*** (0.011)	0.016** (0.007)
Exposure	−0.001 (0.004)	0.000 (0.007)	−0.000 (0.004)	0.001 (0.007)	−0.001 (0.004)
Muslim* Exposure	0.001 (0.006)	−0.006 (0.010)	0.001 (0.006)	−0.006 (0.010)	0.001 (0.006)
			Panel D (Muslim population only)		
Exposure	0.001 (0.005)	0.001 (0.005)	−0.012** (0.005)	0.001 (0.005)	0.001 (0.005)

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Table A3. Estimates of marginal effects of exposure to Ramadan fasting period on stunting by months of exposure- Weighted regressions

	(1) Global	(2) Most recent-born	(3) Control HDI	(4) Control GDPPCAP	(5) Control HXPDPCAP
Month_0	0.002 (0.016)	−0.010 (0.020)	0.002 (0.016)	0.001 (0.016)	0.001 (0.016)
Month_1	0.044*** (0.013)	0.033** (0.016)	0.045*** (0.013)	0.043*** (0.013)	0.043*** (0.013)
Month_2	0.022 (0.014)	−0.002 (0.017)	0.023* (0.014)	0.021 (0.014)	0.023 (0.014)
Month_3	0.033** (0.015)	0.020 (0.018)	0.034** (0.015)	0.033** (0.015)	0.033** (0.015)
Month_4	−0.015 (0.013)	0.005 (0.016)	−0.016 (0.014)	−0.015 (0.014)	−0.016 (0.013)
Month_5	−0.028* (0.016)	−0.033* (0.018)	−0.028* (0.016)	−0.027* (0.016)	−0.029* (0.016)
Month_6	−0.027** (0.013)	−0.016 (0.016)	−0.028** (0.013)	−0.027** (0.013)	−0.028** (0.013)
Month_7	0.000 (0.014)	0.020 (0.017)	−0.001 (0.014)	0.001 (0.014)	0.000 (0.014)
Month_8	0.002 (0.015)	0.005 (0.017)	0.001 (0.015)	0.002 (0.015)	0.002 (0.015)
Month_9	−0.015 (0.014)	0.002 (0.018)	−0.016 (0.014)	−0.015 (0.014)	−0.015 (0.015)
HDI			−0.329 (0.226)		
GDP per head				0.082 (0.081)	
HXPDPCAP					−0.037 (0.024)
N	69,753	46,984	69,644	69,644	67,611

Table A4. Estimates of marginal effects of exposure to Ramadan fasting period on underweight by months of exposure- Weighted regressions

	(1) Global	(2) Most recent-born	(3) Control HDI	(4) Control GDPPCAP	(5) Control HXPDPCAP
Month_0	−0.012 (0.013)	−0.007 (0.016)	−0.011 (0.013)	−0.011 (0.013)	−0.013 (0.013)
Month_1	−0.000 (0.012)	0.008 (0.014)	0.002 (0.012)	0.003 (0.012)	−0.001 (0.012)
Month_2	0.004 (0.012)	0.000 (0.014)	0.007 (0.012)	0.008 (0.012)	0.003 (0.012)
Month_3	0.007 (0.012)	−0.012 (0.014)	0.007 (0.012)	0.007 (0.012)	0.006 (0.012)
Month_4	−0.016 (0.011)	0.010 (0.014)	−0.017 (0.012)	−0.019 (0.012)	−0.014 (0.012)
Month_5	−0.005 (0.013)	−0.009 (0.016)	−0.007 (0.013)	−0.008 (0.013)	−0.004 (0.013)
Month_6	0.002 (0.012)	0.012 (0.015)	0.001 (0.012)	−0.000 (0.012)	0.003 (0.013)
Month_7	−0.016 (0.012)	0.002 (0.015)	−0.019 (0.012)	−0.019 (0.012)	−0.016 (0.012)
Month_8	−0.025** (0.012)	−0.015 (0.016)	−0.027** (0.012)	−0.027** (0.012)	−0.025** (0.012)
Month_9	−0.028** (0.013)	−0.009 (0.016)	−0.029** (0.013)	−0.029** (0.013)	−0.028** (0.013)
HDI			−0.683*** (0.166)		
GDP per head				−0.314*** (0.063)	
HXPDPCAP					0.054*** (0.020)
N	69,688	46,928	69,579	69,579	67,546

Note: All models includes control for child age, birth order, single or multiple births, mothers age, household size, household head age, mass media expsoure, wealth status, country and time dummies.
Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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