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Impact of prenatal exposure to Ramadan on disability in Pakistan among adults age 18–64

Theresa Thompson Chaudhry *

Department of Economics, Lahore School of Economics, Intersection Main Blvd DHV Ph VI and Burki Rd., Burki (Lahore) 53200, Pakistan

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ABSTRACT

Purpose: Temporary disruptions to eating and sleeping patterns due to exposure to Ramadan during pregnancy have been shown to increase the probability of disability and chronic health problems later in life. This study aims to analyze the intent-to-treat effect of prenatal exposure to Ramadan (the Islamic month of fasting) on individual disabilities for individuals age 18 to 64 across three provinces encompassing 94% of Pakistan's population.

Subjects and methods: The study uses observational data from 2017 to 2019 by the UN-supported Multiple Indicator Cluster Survey (MICS) on 187,265 adults in Punjab, 71,895 adults in Sindh, and 91,283 in Khyber Pakhtunkhwa, Pakistan. Excluding data on those age > 64 and observations with incomplete data, multivariate regression analysis was conducted on the data of around 277,000 individuals to assess the risk of disability due to pregnancy coinciding with Ramadan.

Results: Considering exposure to Ramadan by calendar month prior to birth, women exposed in particular months have lower rates of disability related to sight (− 0.3 percentage point, $p < 0.1$), memory (− 0.3 pp., $p < 0.05$), and mobility (− 0.6 pp., $p < 0.05$) but a higher chance of hearing problems (0.2 pp., $p < 0.1$) as compared to women who were not exposed in utero, while men exposed in particular months have a higher likelihood of a disability in sight (0.5 pp., $p < 0.05$), hearing (0.4 pp., $p < 0.05$), communication (0.5 pp., $p < 0.01$), memory (0.5 pp., $p < 0.05$), or mobility (0.9 pp., $p < 0.01$) as compared to men who were not exposed to Ramadan and women who were similarly exposed. Considering the provinces separately, the results were dominated by Punjab where overlap of pregnancy with Ramadan increased the likelihood of men experiencing a severe disability in hearing, communication, memory, or mobility. Men in Sindh were more likely to experience a memory or mobility disability, and men in Khyber Pakhtunkhwa were less likely to experience a communication or memory disability.

Conclusions: Pregnant women should be counseled regarding the alterations in eating, nutrition, and sleep patterns that may occur during Ramadan, as exposure to Ramadan during pregnancy increases rates of sight, hearing, memory, communication, and mobility disabilities in men.

1. Introduction

A number of studies have found prenatal exposure to Ramadan during pregnancy is related to a variety of chronic health problems and disabilities later in life: higher prevalence of symptoms consistent with cardiac disease and diabetes in older Muslim Indonesians [1]; sight, hearing, and mental/learning deficits in Uganda and psychological problems in Iraq [2]; and poor labor market and socio-economic outcomes [2–5].

2. Subjects and methods

We used data on adults aged 18–64 years from the district-based Punjab Multiple Indicators Cluster Survey (MICS) 2017–18 [23] the Sindh MICS 2018–19 [24], and the Khyber Pakhtunkhwa MICS 2019 [22]. Together, these three provinces make up 94% of Pakistan's population. The Pakistan Bureau of Statistics designed the sample with technical advice from the United Nations International Children's Emergency Fund (UNICEF). After selecting enumeration areas from sampling domains, 12 households (16 households) were interviewed from each urban (rural) enumeration block. Summary statistics on men and women are provided separately in Appendix Table 1 and an age distribution of the sample can be found in Appendix Fig. 1.

We apply an intent-to-treat methodology to investigate the impact of exposure to Ramadan during pregnancy, following the methodology of a number of recent studies [1,2,6,7]. Using methods adapted from Almond and Mazumdar [2], we use month- and year-of-birth information and, assuming a pregnancy as lasting 40 weeks, we calculate the share of each of

* Corresponding author.
E-mail address: theresa@lahoreschool.edu.pk.

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the nine calendar months prior to the month-of-birth overlapping with the month of Ramadan. In this way, we are able to compare the disability status of individuals exposed to Ramadan in utero (regardless of whether or not their mother fasted) to a control group consisting of those not exposed because their time gestating did not likely overlap with Ramadan.

Even if we had information on fasting during pregnancy, it would still be preferable to ignore this information in favor of the ITT framework, since excluding those who did not fast would bias the estimated impact of exposure to Ramadan while pregnant. This is because a pregnant woman's decision to fast is correlated with other important (but unobserved) factors affecting the probability of disability in offspring: the woman's underlying health status, her health knowledge, and complications impacting the pregnancy [8,9]. Regardless, pregnant women in Pakistan self-report fasting at substantial rates, with 90% fasting at least some days and two-thirds fasting daily or on alternating days [10].

We employ the following linear probability model with geographic fixed effects to analyze the impact of prenatal exposure to Ramadan on the incidence of disability:

$$\begin{aligned} Disability_{ic} = {} & \boldsymbol{\beta_1}\mathbf{RamadanExposureInUtero}_{ig} \\ & + \boldsymbol{\beta_2}\mathbf{RamadanExposureInUtero}_{\boldsymbol{ig}} \times \mathrm{Male}_{ig} + \beta_3 \mathrm{Male}_{ig} \\ & + \beta_4 \mathrm{JanBirth}_{ig} + \boldsymbol{\beta_5}\mathbf{RamadanExposureInUtero}_{\boldsymbol{ig}} \\ & \times \mathrm{JanBirth}_{ig} + \beta_6 \mathrm{JanBirth}_{igig} \\ & + \boldsymbol{\beta_7}\mathbf{RamadanExposureInUtero}_{\boldsymbol{ig}} \times \mathrm{Male}_{igig} + \gamma \boldsymbol{YOB}_{ig} \\ & + \lambda \boldsymbol{MOB}_{ig} + \theta \boldsymbol{W}_{ig} + \lambda \boldsymbol{G}_i + \varepsilon_{ig} \end{aligned} \quad (1)$$

where $Disability_{ic}$ is an indicator variable for disability (1 = disabled, 0 otherwise) for individual i living in area g, where disability in each domain entails that the individual either has a lot of difficulty or cannot perform the activity at all, and ***RamadanExposureInUtero*** is the vector of exposure variables measuring the overlap of Ramadan with pregnancy. We begin by calculating the share of each of the nine calendar months (prior to the month-of-birth) overlapping with Ramadan, in addition to exposure in the month of birth, following Almond & Mazumdar [2]. Since the Islamic calendar is lunar, Ramadan frequently begins in one month of the Gregorian calendar and ends in another, so that the exposure variable resembles a continuous variable ranging in value from 0 to 1. We use the exposures by calendar month prior to birth plus exposure in the month-of-birth in our main specifications. In others, we sum the calendar month exposures to create an overall exposure to Ramadan variable or exposure by stage of pregnancy (early, mid, or late). Given that we only have data on the calendar month and year of birth, our measure of Ramadan exposure in utero will be most accurate for individuals born near the middle of the month, capturing their exposure in utero from conception up to the completion of 40 weeks.[1]

By including a male gender indicator and its interaction with measures of exposure to Ramadan in utero, we are effectively using women as an additional control group against whom men are being compared. The differentiated effects by gender are our main results since placental and fetal growth and, it is suspected, their adaptations to environmental stressors, vary by gender [11–13]. In some specifications we instead estimate the impact of exposure in utero without gender interactions, either using the whole sample or gendered sub-samples, so that all gender indicators and their interactions are dropped from Eq. 1. In those specifications using gendered sub-samples, we are comparing men (women) exposed in utero to Ramadan only to other men (women) who were not exposed.

We also include a number of controls: ***YOB*** is a vector of year-of-birth indicators for birth years 1969–2001; ***MOB*** is a vector of month-of-birth indicators, critical for separating out the effects of exposure to Ramadan from seasonal patterns that may affect birth outcomes such as food availability or infections that are seasonal [14,15]; ***W*** represents the wealth quintile of the individual's household; and ***G*** represent geographic fixed effects, formed as interactions of district and urban/rural indicators. The geographic fixed effects control for all time-invariant factors, both observed and unobserved, such as local health infrastructure and environmental factors that could impact disability status and differ between areas but are common to individuals residing there. Since a disproportionate share of births are recorded in January, a share of which are likely misreported, we also interact the exposure variables with an indicator for January births, *JanBirth*, in order to segregate potentially problematic observations from the rest of the sample.

3. Results

For the sample of all three provinces and measuring exposure to Ramadan in early, mid, and late pregnancy, we find that individuals exposed to an entire month of Ramadan, compared to those who were not exposed to Ramadan at all, have a 0.1 percentage point (pp) increase in the likelihood of severe disability affecting hearing, and a 0.1 pp. decrease in the likelihood of a severe disability affecting memory (Table 1, Panel A). In panels B and C of Table 1, we find that the impact on hearing is due is restricted to men. Female subjects exposed prenatally to the entire month of Ramadan, compared to women who were not exposed at all, are 0.4 pp. less likely to have a mobility disability, meaning “a lot difficulty” walking or dressing or not being able to do these activities at all, significant at the 5% level (Table 1, Panel A). When we compare men to women in the same specification using interactions of gender with exposure to Ramadan, men exposed in utero are 0.3 pp. ($p < 0.05$) and 0.5 pp. ($p < 0.01$) more likely to experience a communication or mobility disability as compared to men who were not exposed and women who were similarly exposed (Table 2, Panel D).

When we disaggregate further and consider exposure by calendar month prior to birth (Table 2), we see that exposed men have a higher likelihood for all five types of disability as compared to men who were not exposed to Ramadan and women who were similarly exposed; exposed women have lower rates of most disabilities. Aggregating exposure to Ramadan over the months of pregnancy or estimating a single impact for men and women together therefore hides significant heterogeneity.

Considering the three provinces separately in Appendix Table 2, we see that the results are strongest for Punjab, where men exposed to Ramadan during pregnancy have higher rates of a severe disability (0.4–0.6 pp) in hearing, communication, memory, or mobility (with p-values ranging $p < 0.1$ to $p < 0.001$) as compared to men who were not exposed and women who were similarly exposed (Appendix Table 2, Panel A). In Sindh, men exposed to Ramadan in utero have a 0.9 pp. increase in the likelihood of a severe memory or mobility disability ($p < 0.1$ to $p < 0.01$), as compared to men who were not exposed and women who were similarly exposed (Appendix Table 2, Panel B). In contrast, men in Khyber Pakhtunkhwa were *less* likely to have a severe disability related to communication or memory ($p < 0.1$ to $p < 0.05$) as compared to men who were not exposed and women who were similarly exposed (Appendix Table 2, Panel C). Women in Punjab and Sindh exposed to Ramadan in utero were found to be less likely to have a disability, especially in memory, as compared to women who were not exposed, while the opposite is the case for women in Khyber Pakhtunkhwa. Looking at Punjab in more detail, we find that the impacts of exposure to Ramadan in utero are concentrated among men in rural areas for memory (Appendix Table 3, Panel A) and men in urban areas for hearing problems (Appendix Table 3, Panel B).

The fragile male hypothesis suggests that males have higher rates of disease and mortality throughout the life cycle [16]. Even the sex ratio may be sensitive to prenatal conditions, and evidence of missing males has been found when there is in utero exposure to famine, Ramadan, or even breakfast skipping [2,17–19] although this finding is not universal [2,20]. Using

[1] We take a conservative approach to indicating exposure in utero to Ramadan. If the majority of Ramadan occurs in the tenth calendar month before birth, so that Ramadan ends before the middle of the likely conception month, we categorize them as probably not exposed and include them in the control group. Similarly, if Ramadan does not begin until after the middle of the calendar month an individual is born, we categorize them as probably not exposed and include them in the control group. Our measure will therefore, in a small number of cases, slightly underestimate (overestimate) the exposure to Ramadan for those born late (early) in the same calendar month as Ramadan, if Ramadan begins after the middle of the calendar month. It will also slightly underestimate (overestimate) in a small number of cases the exposure for those conceived early (late) in the same calendar month as Ramadan, if Ramadan ends before the middle of the calendar month.

Table 1
Impact of child exposure to ramadan on disability, full sample.

	(1)	(2)	(3)	(4)	(5)
	Sight	Hearing	Communication	Memory	Mobility
Panel A: Full Sample, Main Effect					
Early Pregnancy Ramadan Exposure	0.000	0.001 +	0.000	−0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Mid Pregnancy Ramadan Exposure	−0.001	0.001	0.001	−0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Late Pregnancy Ramadan Exposure	0.000	0.000	0.000	−0.001 +	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	277,744	277,813	277,929	277,922	277,823
Panel B: Males, Full Sample					
Early Pregnancy Ramadan Exposure	0.000	0.002*	0.001	−0.000	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Mid Pregnancy Ramadan Exposure	−0.001	0.001	0.001	0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Late Pregnancy Ramadan Exposure	0.001	0.001	−0.000	−0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	138,636	138,680	138,748	138,739	138,694
Panel C: Females, Full Sample					
Early Pregnancy Ramadan Exposure	−0.000	0.000	−0.001	−0.001	−0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Mid Pregnancy Ramadan Exposure	−0.002	−0.000	0.001	−0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Late Pregnancy Ramadan Exposure	−0.001	0.000	0.000	−0.002	−0.004*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Observations	139,086	139,111	139,159	139,161	139,107
Panel D: Full Sample, by Gender					
Early Pregnancy Ramadan Exposure (Female)	−0.000	0.000	−0.001	−0.001	−0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Mid Pregnancy Ramadan Exposure (Female)	−0.002	−0.000	0.001	−0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Late Pregnancy Ramadan Exposure (Female)	−0.001	0.000	−0.000	−0.002 +	−0.004*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Male*Early Pregnancy Ramadan Exposure	0.001	0.002	0.003*	0.001	0.004
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
Male*Mid Pregnancy Ramadan Exposure	0.001	0.001	0.001	0.002	0.000
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
Male*Late Pregnancy Ramadan Exposure	0.003	0.000	0.000	0.002	0.005**
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Observations	277,722	277,791	277,907	277,900	277,801

Notes: Author's calculations. Standard errors in parentheses, $^{+}$ $p < 0.10$, $*$ $p < 0.05$, $**$ $p < 0.01$, $***$ $p < 0.001$.

data from the birth history module from the same three MICS surveys on all births to women age 18 to 49, we test some components of the fragile male hypothesis, including effects on the probability of a male birth and child mortality in response to exposure to Ramadan during pregnancy (Appendix Table 4). The likelihood of a male birth is unrelated to prenatal exposure to Ramadan in any province (App Table 4, Panel A). However, it may be difficult to detect missing male births in Pakistan given local son-biased birth stopping norms, since many couples continue having children until the desired number of sons is reached [21]. We do, on the other hand, find a higher rate of under-5 mortality for males exposed in pregnancy to Ramadan, especially in Punjab (App Table 4, Panel B), offering partial support for the fragile male hypothesis.

Table 2
Impact of child exposure to ramadan on disability by month prior to birth, full sample.

	(1)	(2)	(3)	(4)	(5)
Exposure to Ramadan in the i^{th} calendar month before birth	Sight	Hearing	Communication	Memory	Mobility
Month 9 (female)	−0.001	−0.000	−0.001	−0.002	−0.001
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Month 8	−0.001	0.001	−0.002	−0.000	−0.003
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Month 7	0.001	−0.000	−0.000	0.000	0.001
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Month 6	−0.001	−0.001	0.001	−0.004*	−0.006*
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Month 5	−0.003	0.001	0.002	0.002	0.004
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Month 4	−0.002	0.000	−0.001	−0.002	0.003
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Month 3	−0.001	−0.001	0.001	−0.003*	−0.003
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Month 2	0.001	0.002 +	0.000	−0.002	−0.003
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
Month 1	−0.003 +	−0.001	−0.001	−0.003 +	−0.004
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Month 0 (birth)	−0.001	−0.000	0.000	−0.000	−0.005*
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Male	−0.006***	−0.001	0.000	−0.002	−0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Male* Month 9	0.001	0.003	0.001	0.000	0.004
	(0.003)	(0.002)	(0.002)	(0.002)	(0.004)
Male* Month 8	0.002	0.001	0.005**	0.003	0.007*
	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
Male* Month 7	−0.001	0.001	0.000	−0.001	−0.003
	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
Male* Month 6	−0.000	0.004*	0.002	0.005*	0.008*
	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
Male* Month 5	0.002	−0.000	−0.001	−0.003	−0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)
Male* Month 4	0.001	0.000	0.002	0.003	−0.003
	(0.003)	(0.002)	(0.002)	(0.002)	(0.004)
Male* Month 3	0.004 +	0.002	−0.001	0.001	0.005
	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
Male* Month 2	−0.002	−0.001	0.002	0.004 +	0.009**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Male* Month 1	0.005*	0.002	0.000	0.001	0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Male*Month 0 (birth)	0.003	−0.001	−0.001	−0.002	0.005
	(0.003)	(0.002)	(0.002)	(0.002)	(0.004)
Observations	277,722	277,791	277,907	277,900	277,801

Notes: Author's calculations. Standard errors in parentheses, $^{+}$ $p < 0.10$, $*$ $p < 0.05$, $**$ $p < 0.01$, $***$ $p < 0.001$.

4. Conclusion

Similar to Almond and Mazumdar [2], we find that the disabilities occurring as a result of Ramadan exposure during pregnancy are related to sight, hearing, and cognitive deficits. In our study, it affected all five disabilities in men in the full sample of three provinces (Table 2). Almond and Mazumdar found for Uganda and Iraq that Ramadan exposure in pregnancy was related with similar effect sizes to: sight (0.35 percentage points), hearing (0.24 pp), mental and learning deficits (0.25 pp), and psychological problems (0.23 pp), although they did not estimate these effects separately by gender. The types of disabilities found by Almond and Mazumdar [2] to be related to prenatal Ramadan exposure overlapped between the two countries they considered, but not completely. Congruence regarding the particular disabilities found to be related to exposure to Ramadan during pregnancy has not yet been achieved in the literature.

Among men in our sample, the rates of severe disability are 1.2% in sight, 0.6% in hearing, 0.6% in communication, 0.9% in memory, and 2.2% in mobility (Appendix Table 1). This makes the estimates of Ramadan

exposure during pregnancy of a 0.4–0.9 percentage point increase in disabilities a meaningful result.

Given that our ITT framework retains non-fasting subjects within the treatment group, the estimate of the effect of exposure to Ramadan during pregnancy will tend to be conservative. Nonetheless, for the ITT approach to be valid, couples should not actively time their pregnancies to avoid overlap with Ramadan, as this would reintroduce selection bias into our estimates. We cannot test for pregnancy timing directly this our study, so it remains an open question in the literature and in Pakistan in particular. Future work using mothers' full birth histories may shed further light on the issue.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Appendix Table 1
Descriptive Statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Males 18–64					
Sight: Severely Disabled = 1	138,555	0.012	0.107	0	1
Hearing: Severely Disabled = 1	138,595	0.006	0.075	0	1
Communication: Severely Disabled = 1	138,673	0.006	0.078	0	1
Memory: Severely Disabled = 1	138,667	0.009	0.093	0	1
Mobility: Severely Disabled = 1	138,694	0.022	0.148	0	1
Exposure: Share of Ramadan overlapping with pregnancy	138,694	0.817	0.35	0	1
Share of Ramadan overlapping with early pregnancy	138,694	0.254	0.407	0	1
Share of Ramadan overlapping with mid pregnancy	138,694	0.225	0.384	0	1
Share of Ramadan overlapping with late pregnancy and birth month	138,694	0.339	0.447	0	1
Wealth Quintiles					
Poorest	138,694	0.196	0.397	0	1
Second	138,694	0.207	0.405	0	1
Middle	138,694	0.212	0.409	0	1
Fourth	138,694	0.193	0.395	0	1
Richest	138,694	0.191	0.393	0	1
Females 18–64					1
Sight: Severely Disabled = 1	138,982	0.017	0.129	0	1
Hearing: Severely Disabled = 1	139,006	0.006	0.078	0	1
Communication: Severely Disabled = 1	139,077	0.005	0.069	0	1
Memory: Severely Disabled = 1	139,083	0.01	0.1	0	1
Mobility: Severely Disabled = 1	139,107	0.029	0.169	0	1
Exposure to Ramadan in utero (share of Ramadan overlapping with pregnancy)	139,107	0.82	0.346	0	1
Share of Ramadan overlapping with early pregnancy	139,107	0.258	0.41	0	1
Share of Ramadan overlapping with mid pregnancy	139,107	0.229	0.386	0	1
Share of Ramadan overlapping with late pregnancy and birth month	139,107	0.333	0.444	0	1
Wealth Quintile					
Poorest	139,107	0.196	0.397	0	1
Second	139,107	0.203	0.402	0	1
Middle	139,107	0.209	0.407	0	1
Fourth	139,107	0.196	0.397	0	1
Richest	139,107	0.195	0.396	0	1

Source: Author's calculations based on Punjab MICS 2017–18, Sindh MICS 2018–19, & Khyber Pakhtunkhwa MICS 2019.

Appendix Table 2
Impact of Child Exposure to Ramadan on Disability by Province.

	(1)	(2)	(3)	(4)	(5)
	Sight	Hearing	Comm	Memory	Mobility
Panel A: Punjab					
Early Pregnancy Ramadan Exposure (Female)	−0.000	−0.001	−0.003**	−0.004*	−0.003
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Mid Pregnancy Ramadan Exposure (Female)	−0.003	−0.001	−0.001	−0.003	0.001
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Late Pregnancy Ramadan Exposure (Female)	0.000	−0.001	−0.001	−0.003*	−0.004+
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
Male*Early Pregnancy Ramadan Exposure	0.003	0.004*	0.006***	0.006**	0.005
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Male*Mid Pregnancy Ramadan Exposure	0.001	0.004**	0.002	0.004+	−0.001

Appendix Table 2 (*continued*)

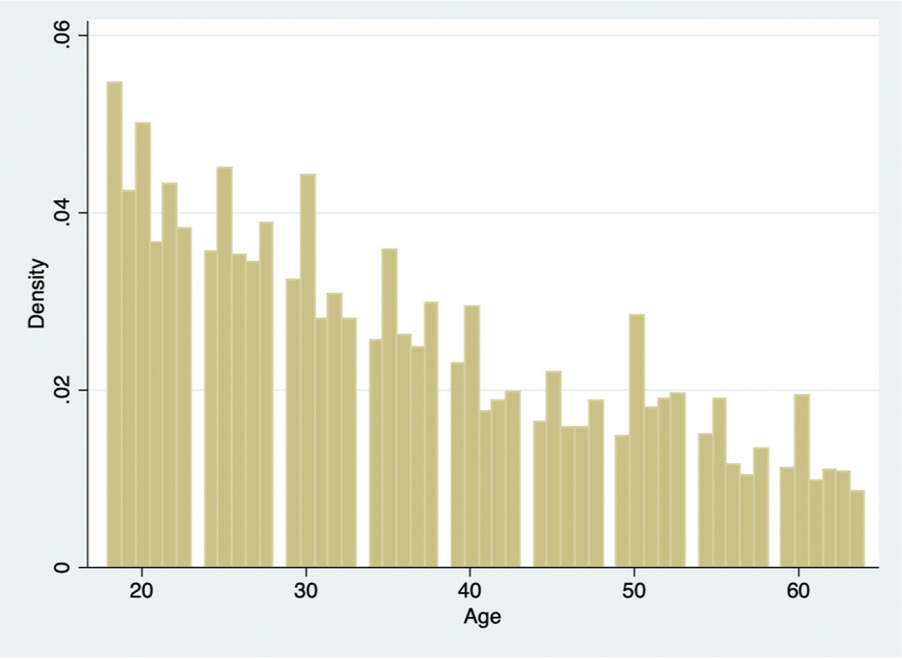
	(1)	(2)	(3)	(4)	(5)
	Sight	Hearing	Comm	Memory	Mobility
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Male*Late Pregnancy Ramadan Exposure	0.002	0.001	0.001	0.004^{+}	0.005^{+}
	(0.002)	(0.001)	(0.002)	(0.002)	(0.003)
Observations	136,916	136,926	136,925	136,924	136,884
Panel B: Sindh					
Early Pregnancy Ramadan Exposure (Female)	0.003	0.002	0.000	0.001	0.000
	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)
Mid Pregnancy Ramadan Exposure (Female)	0.002	0.001	0.001	−0.003	−0.005
	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)
Late Pregnancy Ramadan Exposure (Female)	0.001	0.000	−0.003	−0.005+	−0.010*
	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)
Male*Early Pregnancy Ramadan Exposure	−0.002	0.001	0.001	−0.000	0.002
	(0.004)	(0.003)	(0.003)	(0.004)	(0.005)
Male*Mid Pregnancy Ramadan Exposure	0.001	−0.000	0.002	0.004	0.012*
	(0.004)	(0.002)	(0.003)	(0.003)	(0.005)
Male*Late Pregnancy Ramadan Exposure	0.004	0.001	0.004	0.006+	0.013**
	(0.003)	(0.002)	(0.002)	(0.003)	(0.005)
Observations	59,447	59,447	59,453	59,449	59,430
Panel C: Khyber Pakhtunkhwa					
Early Pregnancy Ramadan Exposure (Female)	−0.002	0.002	0.002	0.004+	−0.000
	(0.003)	(0.002)	(0.001)	(0.002)	(0.003)
Mid Pregnancy Ramadan Exposure (Female)	−0.002	0.002	0.003*	0.003	0.004
	(0.003)	(0.002)	(0.001)	(0.002)	(0.004)
Late Pregnancy Ramadan Exposure (Female)	−0.004+	0.001	0.003*	0.002	0.000
	(0.002)	(0.002)	(0.001)	(0.002)	(0.003)
Male*Early Pregnancy Ramadan Exposure	−0.002	−0.002	−0.003	−0.007*	0.004
	(0.004)	(0.002)	(0.002)	(0.003)	(0.005)
Male*Mid Pregnancy Ramadan Exposure	0.001	−0.002	−0.003	−0.004	−0.003
	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)
Male*Late Pregnancy Ramadan Exposure	0.002	−0.002	−0.003+	−0.005+	0.003
	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)
Observations	81,359	81,418	81,529	81,527	81,487

Notes: Author's calculations. Standard errors in parentheses, $^{+}$ $p < 0.10$, $*$ $p < 0.05$, $**$ $p < 0.01$, $***$ $p < 0.001$.

Appendix Table 3
Impact of Child Exposure to Ramadan on Disability by Rural/Urban Breakdowns (Punjab).

	(1)	(2)	(3)	(4)	(5)
	Sight	Hearing	Communication	Memory	Mobility
Panel A: Rural					
Prenatal Ramadan Exposure (Female)	−0.001	−0.001	−0.002	−0.005*	−0.001
	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
Male*exposed	0.002	0.002	0.003	0.005*	0.003
	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
Observations	93,901	93,910	93,908	93,909	93,877
Panel B:Urban					
Prenatal Ramadan Exposure (Female)	−0.002	−0.002	−0.001	−0.001	−0.004
	(0.003)	(0.002)	(0.002)	(0.002)	(0.004)
Male*exposed	0.002	0.004*	0.004	0.003	0.003
	(0.003)	(0.002)	(0.002)	(0.003)	(0.005)
Observations	43,015	43,016	43,017	43,015	43,007

Notes: Author's calculations. Standard errors in parentheses, $^{+}$ $p < 0.10$, $*$ $p < 0.05$, $**$ $p < 0.01$, $***$ $p < 0.001$.



Appendix Fig. 1. Age distribution of full sample of three provinces.

Appendix Table 4
Investigating the Fragile Male Hypothesis.

	(1)	(2)	(3)	(4)
	All	Punjab	Sindh	Khyber Pakhtunkhwa
Panel A: Male Birth				
Prenatal Ramadan Exposure	0.001	−0.002	−0.000	0.007
	(0.003)	(0.004)	(0.008)	(0.006)
Observations	288,433	149,892	45,073	93,468
Panel B: Under-5 Mortality				
Prenatal Ramadan Exposure (Female)	−0.005*	−0.009*	−0.004	−0.001
	(0.002)	(0.003)	(0.005)	(0.003)
Male*exposed	0.005^{+}	0.009*	−0.002	0.002
	(0.003)	(0.005)	(0.007)	(0.004)
Observations	185,136	98,928	28,850	57,358

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