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Implications of Ramadan intermittent fasting on maternal and fetal health and nutritional status: A review

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Abstract. Fasting and caloric restriction during pregnancy had been reported to impose negative effects on maternal health and pregnancy outcomes. Some research suggests that maternal fasting increases the potential for developing irreversible mental and physical disabilities in children. Even excused, Muslim pregnant women had been accustomed to fast during the ninth lunar month of Ramadan. This comprehensive review aimed at addressing the current evidence pertaining to the effect of Ramadan Intermittent Fasting (RIF) practiced by Muslims pregnant women on maternal and fetal health along with pregnancy outcomes. Current research suggests that maternal fasting during Ramadan has no deleterious impacts on the birth weight or biochemical and biophysical parameters of babies. There is a limited long term research that addressed the effects of RIF on the health of fetuses that were in utero. Milk macro composition was not found to be affected profoundly upon RIF, with significant changes in some micronutrients were reported. Additionally, RIF seems to affect some macronutrients and most micronutrient intakes; therefore, it would be prudent for pregnant and lactating women to utilize the excuse for not fasting during Ramadan. Further research is needed to address the long term consequences of maternal RIF on mother and child health later in life.

Keywords: Maternal and fetal health, Ramadan intermittent fasting, biophysical profile, human milk, doppler indices

1. Introduction

Fasting during the lunar month of Ramadan is one of the five pillars of Islam, which entails that it is obligatory for every healthy adult Muslim to abstain from foods and drinks from dawn to sunset. Fasting during Ramadan encompasses a list of behavioral, lifestyle and dietary modifications [1] that include physical activity, energy and nutrient intakes, sleeping hours and pattern; thus many physiological implications of Ramadan fasting are thought to be noticed during and at the end of the fasting month. Over the past four decades, rising evidence from epidemiologic and clinical studies has supported the health-related benefits of Ramadan intermittent fasting (RIF), including decreased oxidative stress, inflammation and proinflammatory circulating cytokines, reducing body weights and fatness and atherogenic risk factors, and improved insulin sensitivity, blood glucose and variable effects on blood lipids, with no adverse effects of RIF on the heart, liver, kidney, lung, eyes, hematologic profile, neuropsychiatric and endocrine functions [2–5].

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Health status during childhood and adulthood is greatly influenced by maternal health and nutrition during pregnancy and early infancy. Since fasting may pose significant metabolic and physiologic changes on maternal and fetal health; it is worthwhile to study the effect of RIF on the fetal and infant development, and the maternal health during pregnancy and lactation as well. Despite the scarcity of the well-designed studies concerning the effect of RIF on maternal and child health, this review presents the current evidence pertaining to the impact of RIF on maternal health and the different stages of early life including perinatal, fetal and infant stages.

2. Impact of RIF on maternal and child health

2.1. Impact on pregnant and lactating women and embryo

According to the Islamic law, children, pregnant and lactating women are exempted from fasting during Ramadan. Nonetheless, a significant proportion of pregnant and lactating women opts to fast. Fasting and dietary restriction during pregnancy could lead to adverse health effects on pregnant women and might entail poor physical and mental development of the fetus [6]. Good nutrition with balanced diet and oxygen supply during pregnancy are important for proper fetal growth and development [7], especially during the first-trimester for which dietary factors are found to be associated with childhood bone mass, suggesting that fetal nutritional exposures may permanently influence bone development and mineral density [8]. On the other hand, studies conducted on human and animals revealed that the metabolic changes resulting from limited nutrition during pregnancy, especially in the early stages can lead to permanent mental and physical changes in infants [9]. Additionally, it was elucidated that limited nutrient intakes prenatally could lead to certain adaptive metabolic responses in the fetus that may have a negative impact on fetal health, and could lead to the development of chronic ailments such as cardiovascular diseases and diabetes. Further, it was suggested that prenatal nutrition restriction could elicit permanent changes in the neuro-endocrine function, resulting from modification of hypothalamo-pituitary-adrenal (HPA) function, and consequently leading to mental and behavioral dysfunction in infants [9].

After conducting a careful search through the search engine "PubMed", we found out that the number of studies that explored the effect of "Ramadan fasting and pregnancy" did not exceed 52 studies, which is a quite few when compared to the large number of Muslim women practicing the fasting ritual in the whole world. The duration of abstention of pregnant women from eating and fasting during Ramadan ranges from 12–17 hours depending the length of the day time during the solar season. This may influence the embryo and nursing baby health in varying degrees according to the seasonal climate conditions and nutritional status of the nursing mother. This instigated several researchers to investigate the influence of mother fasting during Ramadan on the health of the embryo as well as on the composition of the lactating mother milk.

Many pregnant and lactating mothers insist on practicing the fasting ritual in Ramadan despite the fact that they have the jurisprudent excuse not to fast in such situations because it may inflict a negative effect on the mother or baby health [10]. Muslim women showed a strong compassion for fasting during pregnancy despite overall decrease in maternal health indicators [11]. This phenomenon is reflected in a study, which indicated that pregnant or lactating Muslim women tend to avoid talking to their physician or health care provider in Ramadan to preclude any potential recommendation of ceasing fasting in such situations [12]. Almond and Mazumderz [13] pointed out that most Muslim women (70–92%) including pregnant and lactating women are practicing RIF in different countries of the world including the United States, United kingdom, Yemen, Singapore and Gambia. One study elucidated that almost all lactating and 90% of pregnant women in one of the villages in Western Africa were practicing RIF [14], while 87% of pregnant women were practicing RIF during their pregnancies in Singapore [15] and about 88% in Pakistan [11]. Despite the fact that pregnant women are exempted from fasting, many potential factors may compel them to fast. Family encouragement and adequate support from their spouses and family members [16], lack of severe adversities during fasting by most of the fasting mothers, lack of tendency to fast solely during the year days in compensation to the lost obligatory days from Ramadan, and not to feel guilty or embarrassed for breaking the ritual of fasting inside her community; all reinforce the decision of fasting while being pregnant [17, 18]. In comparison, in a cross-sectional study in Turkey, 46% of lactating women were fasting Ramadan, and significant part of the study group (12.5%) has started introducing solid foods to their babies during Ramadan to minimize the burden of lactation while being fasting [19].

Various studies have explored the effect of RIF on embryo, pregnant woman health and quantity and composition of the nursing mother milk. These studies included the Biophysical Profile (BPP) and Doppler indices including infant size [20, 21, 22], breathing movements of the embryo and uterine arterial blood flow [18, 20, 23]. On the other hand, infant birth weight was the major subject of many other studies [24–28]. Pregnant woman food intake [29] and milk composition of lactating mothers were also studied [30, 31].

2.2. Effect on food intake and biochemical parameters of pregnant women

Inadequate food intake of pregnant woman, especially in the third trimester, may trigger negative implications on the health of the fetus. The conditions of inadequate food intake and the subsequent physiological and biochemical changes that take place are described as accelerated starvation [32]. This physiological stress condition is manifested by decreasing levels of blood glucose, increasing free fatty acids concentration and ketone bodies formation, which mainly occurs after fasting for 12 hours or more [14, 24]. Maternal ketonuria during pregnancy may lead to decreased fetal intelligence, therefore fasting and restricting carbohydrate intake should be avoided during pregnancy.

In a descriptive cross-sectional study conducted on 185 volunteer pregnant women in Iran [20], the effect of calorie restriction as a result of RIF on the extent of hypoglycemia and ketonuria was investigated. The study revealed that 90% and 68% of the subjects exhibited a 500 Kcal/day and 1000 Kcal/day less energy compared to their daily need, respectively. Additionally, a positive correlation was noticed between fasting from one hand and the occurrence of hypoglycemia and ketonuria from the other hand. It was noticed that 32% of the study subjects exhibited ketonuria, while 56% of the subjects had hypoglycemia immediately before they break their fast. In comparison, less than 7% of the pregnant women who took enough amount of food in the same time period experienced ketonuria. Nonetheless, no severe hypoglycemia (<40 mg/dl) was reported in the fasting pregnant women. This suggests that pregnant women can adapt to food and fluid restriction without a major drop in their blood glucose level [20]. This indicates that counter-regulatory reactions may have compensated low blood sugar to higher levels and this was reflected in having no clinical symptoms for the women or their fetuses during the study period that lasted for almost one month [29].

A significant drop in blood levels of glucose, insulin, lactate, and carnitine accompanied by a significant rise in triglycerides (TG), free fatty acids (FFA) and 3-hydroxybutyraye concentrations were reported at the end of the fasting day among the Ramadan fasting women compared to the control group who just undergone a physiological fast. Elevated serum TG was ascribed to the lipolytic effect of prolonged fasting. It could also be due to the high-carbohydrate diets consumption and to less activity and exercise during this month [33]. However, the pregnancy outcome for the study and control group was comparable [24]. On the contrary, no significant differences in the total cholesterol (TC) and TG levels were observed in the fasting group and the control, non-fasting group. Also, it is worthwhile mentioning that HDL levels and HDL/LDL ratio increased in the fasting compared to the non-fasting control group, and this increase in the ratio may be attributed to post-prandial lipemia [33]. Table 1 summarizes the significant biochemical and dietary changes for fasting and non-fasting pregnant women during Ramadan month.

A significant ($P < 0.05$) elevation in serum cortisol levels was observed after 20 days of the fasting month compared to the cortisol levels obtained one week prior to Ramadan [34]. Despite the significantly lower glucose levels in the fasting group, no ketonemia or ketouria was reported in the fasting study group.

Gul et al. [35] assessed food intake and nutritional status of two groups of fasting ($n = 49$) and non-fasting ($n = 49$) pregnant women in Turkey. Blood biochemical parameters of pregnant women were also obtained. Weight gain and energy intake were less in the fasting group compared to the control group. Moreover, the percentages of protein and carbohydrates in total energy source were higher in the fasting group. Although the difference in total energy intake between fasting and non-fasting pregnant women was not studied, maternal weight gain was not statistically different between the fasting and the non-fasting pregnant women in that study. Surprisingly, another study demonstrated that food intake among the Ramadan fasting women increased significantly ($P < 0.05$) in total carbohydrate and energy derived from carbohydrate, while total fat and vitamin A intake were significantly ($P < 0.05$) reduced [30] (Table 1).

The disparity in the results of the biochemical indicators in the fasting women during pregnancy can be ascribed to many potential factors such as differences in the physical activity levels during fasting hours, weather conditions in terms of temperature and humidity, as well as the dietary practices and eating habits during the non-fasting hours (*Iftar*). In Ramadan, and according to the Prophetic Mohammad's directions, people who are legible to fast are highly encouraged to have a good nutritious meal before starting the fasting (*Sahoor* meal) and to delay intake of this meal

Table 1
Changes in biochemical and dietary indicators for fasting and non-fasting pregnant women during Ramadan

Indicator	Sample size and type	Fasting women	Non-fasting women	*P*-value	Reference
Maternal blood glucose (mg/dl)	F = 53	88.8	93.8	0.001	Mirghani et al. (2007)
	NF = 53				
	F = 168	80.0	90.0	0.009	Mirghani et al. (2006)
	NF = 165				
	F = 36	67	90	0.003	Dikensoy et al. (2008)
	NF = 29				
	F = 30*	73.03 ± 1.61	91.13 ± 3.78	0.000	Tug et al. (2011)
Triglycerides (TG) (mg/dl)	F = 56	200.8 ± 52.5	238.4 ± 67.6	0.002	Hilzi et al. (2012)
	NF = 54				
VLDL (mg/dl)	F = 56	43.8 ± 2.2	48.0 ± 1.3	0.01	
	NF = 54				
Ketonuria	F = 56	1	0	0.01	
	NF = 54				
Ketonuria (during the first 4 days of Ramadan)	F = 144	18	6	0.013	Awwad et al. (2012)
	NF = 137				
Ketonuria (during the last 4 days of Ramadan)	F = 82	12	2	0.006	Awwad et al. (2012)
	NF = 79				
Fat energy from total energy intake (%)	F = 21*	28.6 ± 5.7	25.2 ± 3.9	<0.05	Rakicioglu et al. (2006)
Dietary intake of carbohydrates (gm)	F = 21*	243.1 ± 66.7	283.3 ± 66.4	<0.05	
Percentage of carbohydrates energy from total energy intake (%)	F = 21*	58.8 ± 5.9	61.7 ± 4.1	<0.05	
Dietary intake of vitamin A (μg)	F = 21*	996.1 ± 765.0	589.2 ± 549.9	<0.05	
Total antioxidant status (mmol Trolox eq./L)	F (≥10 days) = 17	1.16 ± 0.11	1.08 ± 0.21	≤0.05	Ozturk et al. (2011)

*Comparison between pre- and post- Ramadan fasting or between fasting and postprandial for the same group. F = Fasting, NF = Non-fasting.

to almost the last moment before the declaration of abstention. This meal may minimize the impact of fasting on the metabolic parameters and would alleviate the impact of daytime starvation on brain and bodily functioning.

Although several studies have indicated the occurrence of ketonuria, ketonemia and hypoglycemia, and dehydration in the fasting pregnant women [20, 22, 23, 36, 37], no adverse health effects on the baby or pregnant women were reported. This is attributable to the fact that RIF usually lasts between 12–17 hours, and this fasting period is usually preceded and succeeded by two nutrient-dense meals that are more likely to attenuate the burden of negative effects of fasting on the fetus and pregnant woman. Nonetheless, religiously, it is advisable and allowable for Muslim woman not to fast when being pregnant or lactating.

Normally, low food intake, especially from the antioxidant nutrients and phytochemicals that combat oxidative stress, will trigger the occurrence of more oxidative stress. This is more likely to take place during pregnancy [38]. Notwithstanding, maternal fasting in Ramadan did not pose any negative effect on the total antioxidant status (TAS) and no significant differences were observed between fasting compared to non-fasting pregnant women ($P < 0.05$) in their second trimester. On the contrary women who fasted more than 10 days in Ramadan had significantly ($P = 0.027$) higher TAS compared to non-fasting women [28].

Fasting does not only restrict food intake directly but it may also reduce food intake by enhancing the possibility of having nausea, vomiting and acid reflux problems (Table 2). One study indicated that there was a remarkable increase in vomiting among fasting women during the first month of pregnancy [39]. Other study pointed out that fasting lead to less fluid intake and more dehydration amongst fasting women and this may increase the incidence of urinary tract infections (UTI) [40]. Fasting is high likely to exacerbate dehydration problem and hence increases UTI during during pregnancy. Furthermore, from a single case report of perforated peptic ulcer (PPU) in a pregnant Muslim woman in Nigeria who was fasting during Ramadan, RIF was considered as a risk factor for developing this disease condition [41].

Table 2
Clinical indicators for fasting and non-fasting pregnant women

Indicator	Sample size and type	Fasting women	Non-fasting women	*P*-value	Reference
Total complications	F = 168	46	14	<0.001	Mirghani et al. (2006)
	NF = 156				
Gestational diabetes	F = 168	34	11	<0.001	
	NF = 156				
Induction of labor	F = 168	26	9	<0.001	
	NF = 156				
Caesarean delivery	F = 168	20	7	0.01	
	NF = 156				
	F = 201	57	79	0.027	Awwad et al. (2012)
	NF = 201				
Weight gain (kg)	F = 201	1.6 ± 2.2	2.3 ± 2.0	0.001	
	NF = 201				
Vomiting	F = 200	10	1	0.011	
	NF = 200				
Diarrhea	F = 200	9	0	0.004	
	NF = 201				
Dizziness	F = 201	17	2	0.001	
	NF = 201				

*Comparison between pre- and post- Ramadan fasting or between fasting and postprandial for the same group. F = Fasting, NF = Non-fasting.

Woman's body weight increases dramatically during pregnancy. Maternal weight gain during pregnancy correlates positively with infant birth weight, which is a strong predictor of infant health and development [42]. Most of the weight gain emanates from the developing fetus, placenta, uterus, breast and blood. Practicing RIF during pregnancy was proven to have no effect on maternal weight gain [34]. Abnormal uterine artery Doppler velocimetry (UADV) may be associated with undesirable pregnancy outcome. UADV is affected by many factors such as high altitude, maternal exercise, anxiety and sodium restriction. A cross-sectional observational study was carried out on 106 pregnant women in their second trimester to determine the effect of RIF on the UADV. Unexpectedly, maternal RIF did not lead to any substantial changes in UADV or maternal artery blood flow upon Ramadan fasting [20].

The first trimester is considered the most sensitive stage to maternal nutrient excess and deficiencies [43]. Nonetheless, it was noticed that most pregnant women do not halt fasting during this critical period [26, 44]. In a study conducted in Iran, a random sample of 189 pregnant women were selected, 52% of pregnant women who fasted more than two-thirds of the month days were in their first trimester, whereas 33 and 15% were in their second and third trimesters, respectively [44]. In another study, 4343 pregnant women were randomly selected in the fasting month of 1999 in Iran, of this sample 77% of the women completed the fasting month without cessation while being in their first trimester. In comparison, the rate of fasting women who completed the whole month dropped to 72% and 65% in the second and third trimester, respectively [26].

A cross-sectional study was conducted on 168 fasting pregnant women and 156 control pregnant women to investigate the effect of RIF on pregnancy outcome. The study revealed that the rate of gestational diabetes (GD) and C-section cases were significantly higher in the fasting compared to the control group ($P = 0.001$) and the labor-induced deliveries were 8.4% higher in fasting compared to control group. Additionally, the number of new born babies admitted to the special care baby unit (SCBU) for fasting women were significantly higher ($P = 0.001$) than control group [45] (Table 2). Nonetheless, other study [46] pointed out that the cases of C-section were significantly lower ($P < 0.05$) in fasting compared to control pregnant women. This discrepancy in the impact of RIF on maternal delivery could be ascribed to various pre-existing medical conditions among the nursing mothers, as well as environmental and lifestyle conditions, including dietary ones that could affect the delivery process.

When considering the impact of RIF on the rate of preterm delivery (PTD), Awwad et al. [47] found that RIF did not increase the baseline risk of PTD in pregnant women regardless of the gestational age during which they practiced Ramadan fasting.

Alwasel et al. [21] studied the effect of RIF on placental development and baby birth weight. Although average baby birth weight was normal, mean placental weight and ratio of placental weight to birth weight were lower than European reference values. Slower placental development was reported in fasting women, a matter that could be ascribed to the limited nutrients supply.

3. Effect of RIF on milk composition

Nursing milk composition is significantly affected by the maternal nutritional status and dietary intakes during the fasting month. Fasting by breastfeeding mothers of infants is common during Ramadan. Of 164 interviewed breastfeeding mothers in Turkey, about 52% were fasting during Ramadan, with 22% of 129 mothers of infants aged 6 months or younger had perceived a decrease in their breast milk and 23% an increase in the amount of solid supplements the infant was receiving [48]. Rakicioglu et al. [30] investigated the impact of RIF on maternal nutrition among twenty nine fasting lactating mothers and indicated that RIF negatively affected the status of energy and most nutrients. Nutrients such as zinc, magnesium and potassium levels in breast milk decreased significantly ($P < 0.05$), except for protein and vitamins A, C and E. However, Bener et al. [31] reported no effect of RIF on the macronutrients composition of milk (Table 3).

4. Effect of RIF on fetal development

Several studies have shown no adverse effects on baby weights for pregnant women who practiced RIF, regardless of the pregnancy stage that overlapped with Ramadan [25–28, 49]. Surprisingly, in a study conducted in Birmingham, UK, the average baby weights were higher for women who practiced RIF during their pregnancies compared to those who didn't [24]. In addition, RIF practiced in the second trimester of pregnancy did not lead to any adverse effect on intrauterine fetal development. No significant differences ($P < 0.05$) were found between fasting and non-fasting pregnant women in terms of estimated fetal body weight, fetal femur length, fetal BPP, amniotic fluid Index (AFI), and umbilical artery systole/diastole ratio [34]. Also, other parameters such recumbent length, head circumference, mid-upper arm circumference and Apgar score were all in the normal range [24].

Additionally, another study confirmed that RIF during the second trimester did not elicit any adverse effects on fetal development or birth weight [28]. Moradi [49] has shown that RIF in the second or third trimester didn't adversely affect fetal development and no significant differences were found ($P < 0.05$) in born babies' weights for mothers who practiced RIF and for the control group. In another study, babies born to women who practiced RIF ($n = 284$) had significantly higher birth weights compared to those of the non-fasting control group ($n = 255$), while baby length in both groups was comparable. This probably entails that fasting during Ramadan did not negatively affect maternal nutrient supply to their fetuses [27]. In another study by Alwasel et al. [50], it was indicated that boys whose mothers were in mid gestation during Ramadan were 1.2 cm longer ($P = 0.005$) and girls had a 0.4 week shorter gestation period ($P = 0.04$).

Table 3
Impact of Ramadan fasting on milk composition for fasting mothers

Nutrient	Before Ramadan fasting	After Ramadan fasting	*P*-value	Reference
Total ash (g)	0.21 ± 0.02	0.27 ± 0.04	<0.001	Rakicioglu et al. (2006)
Zinc (mg)	0.15 ± 0.04	0.18 ± 0.03	0.001	
Magnesium (mg)	2.90 ± 0.50	3.30 ± 0.50	0.003	
Potassium (mg)	23.96 ± 5.27	32.27 ± 5.96	<0.001	

5. Effect on fetal biochemical and biophysical profiles

Little information is available on the effect of maternal RIF on fetal biochemical and biophysical properties. A cross-sectional study that included 162 healthy pregnant women divided equally into fasting and non-fasting control groups was conducted to investigate the effect of RIF on fetal BPP [23]. The study showed that vertical amniotic pool depth, mean umbilical artery pulsatility index, and fetal bladder volume were similar in the fasting and the non-fasting groups, except for the fetal breathing movements, which were reduced during maternal fasting (Table 4). This reduction indicates that the BPP of the fetus may be significantly reduced by maternal food and water deprivation during Ramadan and this deprivation is usually accompanied by low blood glucose levels in fasting pregnant women [20, 22, 23, 36, 37]. Another relevant study [20] elucidated that maternal fasting did not affect UADV as indicated by ultrasound examination performed between 20–24 weeks of gestation. This period was specifically selected because it is a better predictor of abnormal pregnancy outcome compared to other stages of pregnancy. The lack of difference in the UADV could be attributed to adaptation of pregnant women uterine artery flow dynamics to acute changes in blood glucose levels, and to short-term alterations in maternal energy balance [51, 52]. Further, fetal development indicators such as maternal weight gain, estimated fetal weight gain, fetal BPP, AFI, and umbilical artery systole/diastole (S/D) ratio were equivalent in the study (Ramadan fasting women) and control groups [34, 35, 37] (Table 4).

In a study, 30 fasting healthy pregnant women and 29 non-fasting healthy women of $\geq$20 weeks of gestation were recruited [34]. Doppler ultrasonography was performed in both groups at the beginning and end of Ramadan month to study the changes in the following measurements: fetal femur length; fetal biparietal diameter; and estimated fetal body weight. Further, umbilical artery systole/diastole ratio, AFI, and fetal BPP were measured. Results revealed that RIF did not lead to a significant adverse effect on intrauterine fetal development or the fetus's health and maternal health [34]. Another study was carried out to assess the influence of RIF on amniotic fluid volume from fasting ($n = 28$) and non-fasting ($n = 25$) pregnant women. The results indicated that RIF did not lead to any significant negative effect on AFI, deepest vertical pocket and amniotic fluid volume [53] (Table 4).

These results were further confirmed in a later study by Hizli et al. [54] who, reported that RIF practiced by healthy 65 women during pregnancy did not adversely affect the AFI, gestational age at delivery, fetal Doppler parameters, cesarean section rate, birth weight or NICU admission. However, lower levels of VLDL, TG and higher incidence of ketonuria were detected in the fasting group.

Having adequate amounts of amniotic fluid (AF) is crucial for having a healthy pregnancy. AF helps in keeping a properly constant temperature around the baby, protecting from heat loss and acting as a cushion against external

Table 4
Biophysical indicators for fetuses and neonates for fasting and non-fasting mothers during Ramadan

Indicator	Sample size and type	Fasting women	Non-fasting women	*P*-value	Reference
Breathing movements	F = 81	51	70	0.001	Mirghani et al. (2003)
	NF = 81				
Neonatal birth weight (gm)	F = 284	3265 ± 444	3165 ± 440	0.009	Kavehmanesh and Abolghasemi (2004)
	NF = 255				
	F = 201	3094 ± 467	3202 ± 473	0.024	Awwad et al. (2012)
	NF = 201				
Large fetal heart accelerations	F = 78	1.1 ± 1.2	3.6 ± 12.8	0.001	Mirghani et al. (2005)
	NF = 75				
Amniotic fluid index (AFI) (mm)	F = 28	189 ± 35.8	166.7 ± 25.3	<0.05	Kamyabi and Naderi (2004)
	NF = 25				
Fetal biophysical profile (BPP)	F = 30*	9.27 ± 0.26	9.93 ± 0.67	0.023	Tug et al. (2011)
Weight of infant for fasting mother who is breast-fed only (gm)	F = 21*	6535.7 ± 921.2	7550.0 ± 1035.3	<0.001	Rakicioglu et al. (2006)
Length of infant for fasting mother who is breast-fed only (cm)	F = 21*	61.8 ± 3.5	66.2 ± 3.1	<0.001	Rakicioglu et al. (2006)

*Comparison between pre- and post- Ramadan fasting or between fasting and postprandial for the same group. F = Fasting, NF = Non-fasting.

shocks and injuries. The volume of the AF is greatly affected by the maternal nutritional status, especially the level of hydration and electrolytes, carbohydrates and protein intake. It was speculated that pregnant women who practices RIF will be potentially more prone to developing dehydration state at the end of the fasting month. This will lead to abnormally small amount of AF, a conditions known as oligohydramnios [55]. Notwithstanding, a study in which 25 fasting and 27 non-fasting pregnant women were recruited to examine the effect of RIF on fetal growth and Doppler indices of pregnancy. The study indicated that RIF has no adverse effect on fetal growth, AF volume or materno-fetal circulation, and no differences were exhibited between the fasting and the control groups [49]. This may be ascribed to the intermittent nature of fasting in Ramadan that allows for rehydration and dietary replenishment after breakfast, which will probably restore normal AF volume (Table 4).

Despite of the possible risks of under-nutrition on the fetal health, especially in the first trimester of pregnancy, many studies have indicated no adverse effects of RIF on fetal health [20, 37, 44]. No significant differences in average weight, length and head circumference of infants were reported for fasting and non-fasting pregnant women [44]. However, the same study have shown that relative risk of low birth weight baby was 1.5 times higher in mothers fasting in the first trimester compared to non-fasting mothers. Therefore, it is advisable for pregnant women not to fast during Ramadan and to take the religious excuse for not abstaining from foods; otherwise appropriate nutritional program should be adopted to sustain normal fetal development. A study that included 110 healthy pregnant women in their third trimester reported that maternal fasting for 10–12 hours did not have a negative effect on Doppler indices, including uterine, umbilical, and middle cerebral artery. Fetal breathing movement and maternal serum glucose levels were significantly lowered by RIF (Table 4), yet higher maternal blood glucose levels and normal breathing pattern were retrieved quickly after having a balanced meal [36]. Hypoglycemia remarkably reduces fetal breathing movement [56]. Yet, normal fetal breathing improved after maternal ingestion of glucose [57]. Generally, insulin decreases while cortisol and growth hormone increases. Cortisol and growth hormone stimulate protein anabolism and consequently the body will maintain the necessary concentrations of amino acids, free fatty acids and glucose [58]. Mirghani et al. [23] suggested that maternal eating every four hours may maintain the fetus in optimal metabolic condition but when this does not happen due to fasting; the healthy fetus adapts well with short periods of hypoglycemia without losing tangible amounts of glycogen stores.

Normal oxygen and glucose supply are indispensable for normal fetal development. Little information is available about the effect of maternal fasting on fetal heart rate. Mirghani et al. [59] reported that fetal heart rate indices for fetuses of pregnant women who were fasting in Ramadan were normal despite the fact that the number of large accelerations in computerized cardiotocography tracing decreased in response to abstention form food and water intake.

Tug et al. [22] enrolled 30 third trimester healthy singleton pregnant volunteers in a study, where BPP, Doppler indices and maternal biochemical tests were evaluated after fasting for 10–12 hours and 1 hour after meal. Neither AFI nor umbilical and fetal middle cerebral artery (MCA) Doppler indices differed between fasting and postprandial measurements. Fasting and postprandial cerebroplacental ratio (CPR) measurements were also not different from each other. Although fasting BPP scores of the subjects were lower than those of after meal, no significant differences were detected between fasting and postprandial states. Blood glucose levels were lower during fasting as expected, but no significant ketonuria was observed.

The effect of RIF on birth weight, placental weight and placental weight to birth weight ratio was studied over four years for 7083 birth deliveries in Saudi Arabia. Placental weight and birth weight to placental weight ratio was lower than normal values. However, birth weight was normal and equivalent to European values [21]. The placenta acts as a nutrient sensor regulating the transfer of nutrients to the fetus, relying on maternal blood supply [60]. Generally, the ability of the placenta to transfer nutrients is reflected in its size; small babies generally come from small placentas. RIF adversely affected placental growth as shown by Alwasel et al. [21]; however, the efficiency is increased so that nutrient supply and hence fetal growth is sustained. Recently, Alwasel et al. conducted another study to investigate the effect of RIF on the size of placenta and birth weight of babies in Tunisia [61]. A sample of 1,321 babies (682 boys and 639 girls) was examined for their body size at birth. In this study, it was reported that babies whose mothers had been in utero during Ramadan were thinner and smaller, and their mothers had smaller placentas, than those whose mothers had not been in utero during Ramadan. Their findings did not differ by trimester of maternal exposure to Ramadan. They were similar in boys and girls and in primiparous and multiparous mothers. The results of this study provide further evidence that changes in lifestyle during Ramadan have intergenerational effects [61].

Cross-Sudworth [58] reported that RIF does not affect either maternal or baby birth weight or length. Nonetheless, tiredness, dehydration and increased UTI are possible problems for fasting pregnant women. Also, increased incidence of hyperemesis gravidarum in fasting women in their first trimester of pregnancy was reported. Nonetheless, RIF may adversely affect pregnancies, where the pregnant women are underweight, malnourished or have underlying medical conditions.

In general RIF did not seem to have an appreciable effect on macronutrients intakes. However, energy and most nutrient intakes except protein and vitamins A and C were reported to lie below daily recommended dietary allowances necessary for lactating women [30]. Zinc, magnesium and potassium were the most prominent nutrients to be affected negatively by fasting. Even though, it is noteworthy to mention that the sample size (21 fasting lactating mothers) in this study was small and no non-fasting lactating mother control was used for comparison purposes.

6. Long-term effects on children and adolescents

Fasting could have adverse effects on child normal growth and development. Little research has been done to address the impact of RIF on children and adolescent health. Based on census data in countries like Iraq and Uganda; Almond and Mazumder [13] reported that the rate of disability, especially mental disability, increased by approximately 20% among children born to women who practiced fasting in their first trimester. Avoiding this possible risk inflicted on born babies is quite difficult for women who usually practice RIF. This is because most women are not aware of their pregnancies till after the first month of pregnancy, which might overlap with the fasting month. Additionally, pregnant women might unknowingly miss the chance of entertaining the jurisprudence excuse of not fasting due to the fact of being pregnant. One plausible solution is to have strict timing and planning of pregnancy and this is by commencing pregnancy shortly after Ramadan to avoid the overlap.

The exposure to RIF during pregnancy may have lasting consequences for adult body size of the offspring. This finding was extracted from a study conducted in Indonesia based on census data, a positive correlation was found between prenatal exposure to RIF and the development of coronary heart disease and type 2 DM [62]. Additionally, it was indicated that children born to women who practiced fasting in their first trimester had poorer cognitive development and educational performance compared to the children of non-fasting women [63], Nonetheless, these studies were not based on data obtained from retrospective or prospective follow-up studies, but merely based on empirical mathematical equations that tried to predict correlation between fasting and the development of certain metabolic and mental disorders in the offspring of the women who allegedly fasted Ramadan.

More recently, by categorizing prenatal exposure according to the relative timing of Ramadan and the individual's birth date, Ewijk et al. [64] reported that adult Muslims who had been in utero during Ramadan were slightly thinner than Muslims who had not been in utero and had shorter stature, being on average 0.80 cm shorter than those who were not exposed to Ramadan prenatally. However, those findings of Ewijk and colleagues were criticized because the data they obtained were derived from a study of adults, and the authors could not determine whether an individual's mother had fasted during Ramadan or not [65].

Another study was conducted to investigate the effect of RIF on the intelligence quotient (IQ) of children of mothers who fasted during their corresponding pregnancies for at least 27 days. This study is a retrospective cohort conducted on 191 children aged between 4 to 13 years, 98 whose mothers fasted throughout Ramadan when they were pregnant (case group) and 93 children whose mothers did not fast (control group). The children were selected from 15 schools via a questionnaire filled out by their mothers. No significant differences were observed between the IQ scores of the two groups. Fasting during gestation did not adversely affect IQ of children whose mothers had fasted during Ramadan while being pregnant [46].

7. Conclusions

Good and balanced nutrition is crucial for maternal and baby health. Some studies have indicated negative influences of RIF on maternal, infant and child health including maternal biochemical parameters and fetal BPP, infant weight and cognitive development. Although severe hypoglycemia is less likely to occur as a result of RIF, ketonuria,

ketonemia, and dehydration are common biochemical changes that occur as a result of RIF. Nonetheless, these changes are quickly reversible at the end of a fasting day and TAS was shown to be promoted by RIF. RIF do not lead to considerable changes in UADV. Most nutrients levels in the breast milk are not affected by maternal fasting, yet some nutrients such as zinc, magnesium and potassium levels in breast milk decrease. Some of the studies addressed in the current review present inconclusive and sometimes contradictory results regarding the impact of fasting on maternal and child health. Despite the lack of a conclusive evidence of the negative effects of fasting on maternal and fetal health, it is advisable that pregnant women not to fast during Ramadan, especially those who are already undernourished, and to plan well for their pregnancies to avoid the overlap with the fasting month. The first trimester of pregnancy is particularly sensitive to nutrient deficiencies and hence fasting in this period could be potentially harmful for fetus. More research is needed to reveal the long term consequences of RIF on maternal and child health, especially the occurrence of chronic diseases and mental development of children born to women who practice RIF.

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