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Nutrition in Pregnancy: Basic Principles and Recommendations

Draga Plećaš[1], Snežana Plešinac[2,3], Olivera Kontić Vučinić[2,3]

[1]Institute of Hygiene and Medical Ecology, Faculty of Medicine, University of Belgrade, Belgrade, Serbia;
[2]Faculty of Medicine, University of Belgrade, Belgrade, Serbia;
[3]Clinic of Obstetrics and Gynecology, Clinical Center of Serbia, Belgrade, Serbia

SUMMARY
Healthy diet in pregnancy should guarantee proper fetal growth and development, maintain (and promote) maternal health and enable lactation. Nutritional counseling and interventions need to be an integral part of antenatal care and continue during pregnancy in order to reduce the risk of maternal, fetal and neonatal complications, as well as the short- and long-term adverse outcomes. Adverse pregnancy outcomes are more common in women who begin the gestation as undernourished or obese in comparison to pregnant women whose weight is within normal ranges. Increased nutritional and energy needs in pregnancy are met through numerous metabolic adaptations; pregnancy is successfully achieved within wide range of variations in energy supply and weight gain. However, if nutrient restriction exceeds the limits of adaptive responses, evidence indicates that fetus will develop the alternative metabolic competence that might emerge as a disease (type 2 diabetes, hypertension, coronary heart disease and stroke) in adult life.
Keywords: pregnancy; nutrition; fetal growth

INTRODUCTION

Well balanced diet has an important role in health throughout the lifecycle and affects the functioning of all body systems. Increased nutritional and energy needs in pregnancy are due to the physiologic changes of mother and metabolic demands of fetus. These are met through numerous physiologic adaptations including changes in nutrient metabolism orchestrated by placental hormones. Still, if the nutritional and energy needs are not met (especially under severe deprivation), evidence indicates that this will result in unfavorable changes of infant weight, size and body composition, and even in an apparently healthy infant, in alteration of metabolic competence that might emerge as a disease in later life [1, 2, 3].

Healthy diet in pregnancy should ensure proper fetal growth, good maternal health and lactation. Good fetal supply is also achieved through increased intestinal absorption or reduced excretion via the kidney or gastrointestinal tract. Nutritional counselling and interventions need to be an integral part of antenatal and pregnancy care.

ANTENATAL CARE – HEALTHY START

A routine healthcare during a woman's reproductive years should include medical care and counselling on healthy behaviors. To optimize pregnancy outcome, nutritional assessment and advice need to be considered before conception including all relevant information regarding nutritional allergies and/or intolerances, weight changes, diet habits and Body Mass Index (BMI; weight in kg/height in m^2). Appropriate weight gain, diet and exercise need to be discussed at the initial visit and periodically throughout the pregnancy. Nutrition counselling should focus on a well-balanced, varied diet plan coherent with food preferences of the pregnant women (Table 1).

Adverse pregnancy outcomes are more common in women who begin the gestation as undernourished or as obese in comparison to pregnant women whose weight is within normal ranges (BMI=18.5-24.9 kg/m^2) [1, 3]. In addition, ovulation is rare in women with total fat below 22% [4]. Even in women who are normally nourished, but are exposed to acute malnutrition or starvation, absence of ovulation occurs very quickly. Anovulatory infertility is attributed to malnourishment, but is also often diagnosed in overweight or obese women.

Maternal malnutrition increases the risks of low birth weight (<2,500 g), premature birth, fetal growth retardation, small-for-gestational-age (SGA) infants and is associated with perinatal morbidity and mortality; insufficient intake of certain nutrients is related to some fetal congenital anomalies and birth defects. Gestational underweight has also been linked to infant inclination to certain chronic illnesses (diabetes mellitus type 2, hypertension, coronary disease, and stroke) in adulthood (hypothesis of fetal origin of adult disease) [1, 3].

Besides the availability of nutrients, an adequate blood supply, i.e. well developed uterine circulation is also essential for intrauterine fetal growth. Angiogenesis is stimulated by the

Correspondence to:
Draga PLEĆAŠ
Cara Uroša 36, 11000 Belgrade
Serbia
draga.plecas@gmail.com

Table 1. Factors affecting nutrition during pregnancy

Factors affecting nutrition	Preconception undernourishment or overweight/obesity
	Insufficient or excessive weight gain
	Maternal age (adolescents/especially first 2 years after menarche, age > 35)
	Psychological, social, cultural and religious factors that influence nutrition
	History of obstetric complications
	Chronic diseases
	Multiple pregnancy
	Substance abuse
	Nutritional disorders (anorexia, bulimia)
	Nutritional allergies and intolerances
	Sedentary life style/reduced physical activity

increased needs of fetus and occurs through vasodilatation and development of new blood vessels. The endometrium, decidua and placenta are good sources of angiogenic growth factors [5].

Concentration of water-soluble nutrients in maternal plasma is lower in pregnancy than in the non-pregnant state, while the situation is reverse for the liposoluble nutrients. Glucose crosses placenta by facilitated diffusion and provides 75% of energy needs to the fetus. Amino-acids are transferred against concentration gradients, and fatty acids by simple diffusion (fat synthesis occurs in fetal tissues). Ketone bodies produced by maternal lipolysis cross the placenta freely by diffusion.

ENERGY REQUIREMENTS AND RECOMMENDED WEIGHT GAIN IN PREGNANCY

Energy intake is monitored by weight gain during pregnancy. Recommendations are given in respect to BMI before conception. Generally accepted American Institute of Medicine (IOM) 2009 recommendations on weight gain [6] originate from the recommendations issued in 1990; the difference being that recent ones are based on the World Health Organization (WHO) BMI categories and include specific recommendations for gestational weight gain for overweight and obese pregnant women (Table 2). Premature labor, impaired intrauterine fetal development and failure to initiate lactation are more common in pregnant women with insufficient weight gain. On the other hand, pregnant women that gained more weight than recommended deliver macrosomic infants, have greater rate of hypertensive disorders of pregnancy, Cesarean sections and more difficulties in reducing the excessive weight gained during postpartum period [7, 8].

Table 2. Recommended weight gain during pregnancy

BMI before conception (kg/m^2)	Recommended weight gain (kg)	Average weight increase* in II and III trimester (average kg/week)
<18.5 (undernourished)	12.5–18.0	0.51 (0.44–0.58)
18.5–24.9 (normal)	11.5–16.0	0.42 (0.35–0.50)
25.0–29.9 (overweight)	7.0–11.5	0.28 (0.23–0.33)
≥30 (obese)	5.0–9.0	0.22 (0.17–0.27)

* Calculations assume 0.5-2 kg weight gain in the first trimester.

British National Institute for Health and Clinical Excellence advises that, instead of routine follow up on gestational weight gain, the focus should be on individual monitoring of fetal development and potential complications (for example, insufficient weight gain due to growth restriction or excessive gain due to fluid retention in preeclampsia. [3, 8]. Pregnancy outcome was also analyzed among women who began gestation as overweight (BMI=25.0-29.9 kg/m$^{2)}$ and increased their weight less (2.7-6.4 kg) than recommended [9]. It was concluded that, if growth and development of fetus was appropriate, there was no evidence that insisting on weight increase, as per the US Institute of Medicine 2009 recommendations, would produce additional benefit to mother or fetal health. Results of similar research of obese pregnant women provided contradictory results. Recommendations for obese pregnant women were given with the objective to eliminate not only the risks of having large-for-gestational-age infants and obstetric complications, but also small-for-gestational-age infants, preterm births and postpartum weight retention. It is assumed that relationship between the class of obesity of mother on one, and total weight gain during pregnancy on the other side, is very complex. In order to balance the risks of fetal and maternal adverse outcomes, a case to case clinical judgment is required in management of the overweight or obese woman who is gaining less weight than recommended.

Lastly, the assessment of weight gain should also be considered in relation to the extra tissue deposited in pregnancy. A woman that begins pregnancy with appropriate weight (BMI=18.5–24.9 kg/m^2) will gain in average 12.5 kg (fetus 3,400 g; placenta 650 g; uterus 970 g; breasts 405 g; amniotic fluid 800 g; increase in blood volume 1,450 g; increase in fluids 1,480 g; and maternal fat deposits 3,345 g) [10].

Human gestation is characterized by numerous, complex adaptations in energy metabolism of incomparably wider range and potential than mechanisms involved in the non-pregnant state. This metabolic capacity of the species on one, and the fact that fetal growth is very slow process (characteristics of primate reproduction) on the other side, protects and secures fetal growth even under deprived maternal nutrition. Still, despite the effects of such adaptations, intrauterine growth retardation is often encountered in poor environments and can definitely be connected with poor nutrition. Moreover, data based on the birth weight index calculated as a percentage of total increase of mother's weight show that when the increase is small, birth weight accounts for proportionally much greater portion of total increase gained during pregnancy (birth weight represents ~ 25% of total weight gain of well-nourished mother and up to 60% of gestational weight gain in poor communities) [11]. Birth weight shown by this index could be a useful method for assessment of nutrition adequacy during pregnancy.

There is no precise data on total energy costs of normal pregnancy. In general, total costs consist of the energy deposited as new tissue, deposited as fat and as energy required to maintain new tissue. Results vary from 125,000 (additional consumption of energy among pregnant women in Sweden) to -7,000 (reduction of consumption among

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Table 3. Recommendations for energy intake during pregnancy

Recommendations		In the non-pregnant state	During pregnancy (+kcal/day)
Europe		1950–2000	200**
USA		Up to 2200	300***
WHO		1940	285
UK	19–50 years of age	1940	200**
Canada*	19–30 years of age	1900	1st trimester +0
			2nd trimester +340
			3rd trimester+452
	31–50 years of age	1800	1st trimester +0
			2nd trimester+340
			3rd trimester +452

* based on 2006 IOM recommendations;
** only in the last trimester;
*** in the second and third trimester

pregnant women in Gambia) [12]. In well-nourished woman, the basal metabolic rate begins to rise soon after conception and continuously increases until delivery, while in contrast, an undernourished woman shows evident suppression of metabolism that persists to the third trimester of pregnancy [11]. Apparently, there are individual metabolic variations enabling the woman to carry her pregnancy to term under a wide range of nutritional conditions up to the adaptive limits, and consequences of any nutritional deprivation that exceeds these limits as well [1, 3, 8, 11]. Although total costs of pregnancy were strongly correlated with the woman's pre-pregnancy fatness and pregnancy weight gain, it seems that pre-pregnancy nutritional status may be the key factor in modifying the energy costs of gestation (possibly by introducing a system that supervise mother's pre-pregnancy energy status and by adopting economical metabolic mechanisms to fit the individual capacity of pregnant women). The role of leptin and other neuropeptides in achieving this goal remains to be fully understood [13].

In pregnant women with healthy pre-conception weight who gained around 12 kg during gestation, additional energy needs were found to be around 80,000 kcal (Table 3) [3, 11, 14].

Energy needs in multiple pregnancies are greater. Recommended gestational weight gain for the women with twin pregnancies which are well nourished, overweight and obese before conception is 16.8-24.5 kg, 14.1-22.7 kg and 11.3-19.1 kg, respectively [6, 9, 15].

MACRONUTRIENTS

Assuming that an average of 0.8 g/kg of protein/day is taken in the non-pregnant state, and preconception BMI is within normal range, recommended daily intake for protein varies from 51g, i.e. +6 g per day to 71 g per day [2, 16]. Preference is given to sources of animal origin that do not contain too much fat, such as lean meat and fish, milk and dairy products with lower fat content, eggs (egg whites), fresh and dried pulses, grain cereals and nuts. Protein-rich nutrients are at the same time good sources of iron, phosphorus, iodine and B vitamins [15, 17, 18].

Table 4. Recommendations for intake of carbohydrates and fats (% of total energy intake)

Recommendations		Total fats (%)	Total CH (%)	Non-starch polysaccharides (g/day)
WHO	Min.	15	55	16
	Max.	30	75	24
USA		<30	>50	/
Europe		20–30	55–65	Up to 30

Carbohydrates provide 55%-75% of energy needs. Good sources of carbohydrates are cereals and flour products, pulses, potatoes (starchy polysaccharides). Intake of simple sugars should be limited to 10% of energy needs. Fats should provide up to 30 % of daily energy needs (Table 4) [2, 3, 16].

MICRONUTRIENTS

Prominent folate deficiency is connected with the neural tube defects, iodine with the congenital hypothyroidism and neurocognitive deficiencies, iron deficiency causes sideropenic anaemia and increases the risk of low birth weight, premature labor, and perinatal (and maternal) mortality.

Liposoluble vitamins A and D pass freely to placenta by diffusion. If there is no good source of vitamin D in the diet and exposure to sun is minimal, it is advisable to supplement the intake in daily doses of 10 μg of vitamin D/day [3, 18]. Vitamin E and K transfer is very sparse and concentration in fetal tissues and a newborn are lower than in maternal tissues.

Vitamin C is transferred by facilitated diffusion. Concentration in fetal circulation is higher than in the maternal blood. Vitamin C is in competition with glucose for the same placental receptors, but even there is maternal hyperglycemia, there is no evidence of fetal vitamin C deficiency under the circumstances.

Folate (Vitamin B_9) deficiency is present in 5% of general population [3] and thus in early pregnancy. Folate is crucial for synthesis of purine and pyrimidine precursors of nucleic acids, in the metabolism of some amino acids and for initiation of protein synthesis in mitochondria. Fetal levels are 2 to 4 fold higher than in maternal circulation. Transport of folate across the placenta is a complex process that seems to involve several different transport systems. It may be compromised by diet (polyphenolic compounds present in alcoholic and nonalcoholic beverages, some methylxanthines found in coffee and black tea), therapeutic agents (xenobiotics), lifestyle factors (smoking, drug abuse and alcohol consumption) and markers of pathological conditions. Lower folate status has been associated with an impaired fetal growth and neuro-developmental adverse outcomes. Supplementation with 400 μg of folate before conception and during the first 12 weeks of gestation is advised as preventive measure of neural tube defects [2, 19, 20, 21].

Transfer of Vitamin B_{12} is mediated through the vitamin specific receptors. B_6 is transported passively, and B_1 and B_2 by active transport (concentrations are higher in fetal tissues).

Concentrations of calcium are higher in fetal than in maternal tissues – calcium is actively transferred across the placenta, and the same applies for magnesium. Zinc is transported as bound to albumin and it is found in significantly higher concentrations in fetal tissues. Iron transport through the placenta is very intensive, especially in late pregnancy, when fetal needs are highest; placental transferrin receptors facilitate transfer of iron bound to transferrin.

Recommendations on daily intake of certain nutrients during pregnancy are based on standards and assessment of nutritional needs for general population that satisfies the needs of 97.5% of population of certain age (Recommended Daily Allowance – RDA) [18]. If sufficient evidence is not available to calculate the requirement, recommendation is given as an "adequate intake"/AI (Table 5). There are also recommendations which relate to upper limit, i.e. maximum allowed daily intakes which can be taken without risks to mother and/or fetus (with no teratogenic effects) [22].

The iron requirements are not equally distributed over the pregnancy: more of 80% of fetal needs relate to last trimester. Despite physiological changes which ensure increased resorption of iron (about 50% increases in second and up to four times the norm in third trimester), data published by WHO indicate that around 42% of pregnant women have sideropenic anaemia [23]. In addition, iron deficiency in pregnancy is also associated with higher risk of premature labor, low birth weight (<2,500 g), and lower cognitive tests scores [3, 24]. Iron status should be followed up from the very beginning of gestation in order to prevent adverse effects to fetal growth and post-partum anemia in a timely manner, as well as to provide adequate reserves to newborn being breastfed for the first six months. Anemia in pregnancy is defined by hemoglobin (Hb) below 110 g/L, although it is known that during the II trimester the concentration is naturally lower by approximately 5 g/L. Supplementation is mostly indicated by physicians based on individual assessment of each pregnant woman. In the United States, iron supplementation is recommended in lower doses (30 mg/day). Therapeutic doses which can go up to 120 mg of elemental iron are prescribed in treatment of anemia. (WHO does not recommend a certain daily intake but universal supplementation since iron balance does not depend only on the properties of the diet but also and especially on the amounts of stored iron [2, 21]. Daily iron supplementation is associated with reduced risk of anemia, iron deficiency during pregnancy and low birth weight [25]. However, particularly at doses 60 mg of elemental iron or higher, it has been associated with side effects (constipation, nausea, vomiting and diarrhea) and an increased risk of high hemoglobin concentrations in mid and late pregnancy which may be harmful to both mother and infant (late pregnancy hypertension, pre-eclampsia and pregnancy complications). Thus, an intermittent oral iron supplementation (one, two or three times a week on non-consecutive days, alone or in combination with folic acid or other vitamins and minerals) has been proposed as an alternative to daily supplementation in pregnant women who are not anemic and receive adequate antenatal care [26].

Many factors affect the resorption of non-hem iron from supplements: improvement of resorption from vegetables and supplements is facilitated by vitamin C. Resorption is reduced in the presence of polyphenols from tea or coffee.

Additional supplementation containing iron, folate, calcium, magnesium and zinc are often advised in multiple pregnancies.

Table 5. Dietary reference values of micronutrients in pregnancy

Micronutrient/day		Reference value		
		USA	WHO	Europe
Vitamins	Thiamin (mg)	1.4	1.4	1.0
	Riboflavin (mg)	1.4	1.4	1.6
	Niacin[1]	18	18	14
	Vitamin B_6 (mg)	1.9	1.9	1.3
	Vitamin B_{12} (µg)	2.6	2.6	1.6
	Folic acid (µg)	600[2]	370–400[3]	400[4]
	Vitamin C (mg)	80	55	50
	Vitamin A[5]	750	800	700
	Vitamin D[6] (µg)	15[7]	5	10[8]
	Vitamin E[9]	15 mg	0.15–2 mg/kg	>3
Minerals	Calcium (mg)	1000–1300	1000-1200	700
	Phosphorus (mg)	700–1250	1200	550
	Magnesium (mg)	400	220	150–500
	Sodium (mg)	1500[10]	<2000	1600
	Potassium (mg)	4700[10]	3510	3500
	Iron (mg)	27	X[11]	17–21
	Zinc (mg)	12	7.3–13.3	7
	Copper (mg)	1	1	1.2
	Selenium (µg)	60	26-30	60
	Iodine (µg)	220	200	140

[1]as niacin equivalents; [2]as dietary folate equivalents; [3]based on normative storage requirement; [4]assuming bioavailability half of pure folic acid; [5]as retinol equivalents; [6]as cholecalciferol; [7]assuming minimal sunlight; [8]supplement required if exposure to sunlight is limited and BMI>30 kg/m^2; [9]as α-tocopherol; [10]adequate intake; [11]no recommendations, supplementation recommended

SPECIAL RECOMMENDATIONS AND DIETARY RESTRICTIONS IN PREGNANCY

Even though the basic principles are the same as for general population and nutrition is planned around 5 main food groups (bread, cereals and potatoes, fruit and vegetables, milk and dairy products, meat, fish and substitutes/pulses, egg, soya products, food or beverages with high fat and/or sugar content), pregnant women are also advised to [2, 3, 8, 27, 28]:

a) Exclude all food sources which may contain potential teratogens such as food and supplements with high concentrations of vitamin A, medications containing retinoids;

b) Exclude foods which may be bacteriologically unsafe and sources of infection such as listeriosis (immature soft cheeses, unpasteurized milk, pates), toxoplasmosis (undercooked meat, contaminated vegetables), salmonellosis (raw or soft cooked eggs, mayonnaise, undercooked meat, especially chicken);

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c) Use only iodized salt;

d) Since the amount of folic acid required to minimize the risk of developing NTDs cannot be usually achieved through dietary measures alone, folic acid supplementation is recommended as 400 μg/day of folic acid supplement prior to conception and until the twelfth week of pregnancy to all women who may become pregnant;

e) Limit caffeine intake, 200 mg/day (2 cups of coffee);

f) Use lactose-free milk and dairy products if lactase deficiency is diagnosed;

g) Choose foods that are good source of hem iron (meat, fish);

h) Exclude consumption of alcohol, stop smoking and exposure to nicotine smoke (passive smoking);

i) Due to the potential danger of contamination by methyl-mercury (and toxic threats from polychlorinated biphenyls and other lipophilic contaminants) which can cause fetal damage, pregnant and lactating women should avoid eating shark, swordfish, tilefish and king mackerel (big oily fish with potentially high content of methyl mercury). Intake of oily fish low in mercury such are sardines, herring and salmon, should be limited to two portions a week. Contrary to oily fish (contains up to 30 % fat in the tissues), white fish (cod, haddock and flatfish) contain far less fat (1-4%) and the fat is deposited exclusively in the liver;

j) Deficiencies in vegetarian/vegan diet need to be corrected by choice of appropriate natural and/or enriched food and supplements:

- Vitamin D in doses of 5 to 10 μg (200-400 IU) per day;
- Iron in doses of 48.6 mg/day but it is advisable to define the dose after individual assessment;
- Folic acid in doses of 400 to 800 μg;
- Total intake of vitamin B_{12} must be 2.6 μg/day, and is achieved by taking enriched food and/or supplements. Inadequate dietary intake of vitamin B_{12} causes elevated homocysteine levels, which have been associated with adverse pregnancy outcomes including neural tube defects and stillbirth;
- Calcium supplements in doses of 500 mg, if required;
- Zinc supplementation for vegans in doses of 15 mg if the natural sources (legumes, nuts, and whole grains) are not present in diet.

MANAGEMENT OF OVERWEIGHT AND OBESE PREGNANT WOMEN

Obesity in pregnancy is a risk of numerous adverse outcomes and complications including miscarriage, fetal congenital anomalies, thromboembolism, gestational diabetes, pre-eclampsia, dysfunctional labor, postpartum hemorrhage, wound infection, stillbirth, neonatal death. Detection of birth defects may be difficult due to suboptimal view on ultrasound. Administering anesthesia in obese pregnant women is more challenging and need to be planned in advance [39]. Cesarean sections and hypertensive disorders are more prevalent, the breastfeeding rate is lower. Prevalence of overweight and obesity has increased significantly since 1990s all over the world, including Serbia, and the same pattern has been seen among women who get pregnant. [9, 29, 30]. An advice on healthy nutrition and physical activity in relation to the class of obesity (I, II or III) should be given as early as possible (ideally weight should be regulated before pregnancy). Glycoregulation should be tested in all pregnant women that have BMI≥30 kg/m^2 [3, 31, 32, 33].

Nutritional advice for women who are overweight and obese is usually associated with concern regarding safety of calorie-restricted and other weight-losing diets and thus remain challenging until research provides further evidence. The reduction of calorific intake in the second half of the pregnancy with consequential lipolysis and relative ketonemia has been reported to be associated with an impaired mental function of the offspring [3]. The relative ketonemia could be prevented by nutrition plan dominated by intake of high carbohydrates low glycemic index diet (suppression of lipolysis being achieved by the increase of insulin sensitivity induced by such diet regimen). The same diet plan could also help in preventing the onset of gestational diabetes in obese or overweight pregnant women [3, 33]. However, since the consequences of gestational weight change in overweight or obese women are still not completely understood, a preventive approach has been adopted and weight loss during pregnancy is not advised [2, 9].

CONCLUSION

Human pregnancy is successfully achieved within wide range of variations in energy requirements and weight gain. The thresholds for nutrient intakes to support good pregnancy outcomes are not fixed values.

Although the concept of viewing the human fetus as a "perfect parasite" has been long abandoned and replaced with hypothesis of functional plasticity, the implicated metabolic adaptations have their limits ("thrifty metabolism"). The full significance of short- and long-term outcomes of these adaptations require improved study designs, sophisticated statistical models and studies with longer follow up.

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Исхрана у трудноћи: основни принципи и препоруке

Драга Плећаш[1], Снежана Плешинац[2,3], Оливера Контић Вучинић[2,3]

[1]Институт за хигијену и медицинску екологију, Медицински факултет, Универзитет у Београду, Београд, Србија;
[2]Медицински факултет, Универзитет у Београду, Београд, Србија;
[3]Клиника за гинекологију и акушерство, Клинички центар Србије, Београд, Србија

КРАТАК САДРЖАЈ

Правилна исхрана у трудноћи треба да обезбеди правилан раст и развој плода, очува и унапреди здравље мајке и омогући успостављање лактације. У поређењу с трудницама које имају нормалну тежину, неповољан исход трудноће је чешћи међу женама које започињу трудноћу као потхрањене или гојазне. Повећане енергетске и нутритивне потребе у трудноћи обезбеђују се низом физиолошких адаптација које омогућавају да се трудноћа успешно изнесе у оквиру широког опсега енергетског уноса и повећања тежине. Ипак, када се трудноћа одвија у условима који превазилазе физиолошке адаптивне капацитете мајке, има индиција да субоптимална исхрана може да доведе до развоја нарушеног метаболичког модела који се везује за повећану склоност јединке ка неким болестима у одраслом добу (дијабетес мелитус тип 2, хипертензија, коронарна болест, церебрални инсулт).

Кључне речи: трудноћа; исхрана; фетални раст

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