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ORIGINAL CONTRIBUTION

Dietary intake of energy and nutrients in relation to resting energy expenditure and anthropometric parameters of Czech pregnant women

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Abstract
Purpose The aim of this study was to evaluate the dietary intake of energy and nutrients (DIEN) of Czech pregnant women and to assess relationships with body size variables during pregnancy.
Methods One hundred and fifty-two randomly recruited healthy pregnant Czech women, who were normoglycemic, euthyroid, nonsmokers, not anemic, and not users of chronic medications or abusers of alcohol or drugs from countryside and city with different education, were recruited for the study. Anthropometric parameters were measured and resting energy expenditure obtained by indirect calorimetry after 12 h of fasting during four phases of pregnancy. DIEN was evaluated from self-reported dietary intake records over 7 days.
Results Positive correlations were demonstrated between measured resting energy expenditure and intake of energy, substrates and some minerals and vitamins, and negative correlations between DIEN and anthropometric parameters. Lower dietary intake of energy and differences between dietary intake of nutrients and recommended daily allowances during pregnancy of Czech women were documented.
Conclusions The difference between pregnancy body weight and ideal body weight was shown to be a determinant of DIEN. From recent knowledge on prevention of various pathological states, the supplementation or modification of nutritional intake of food with folate, iron, vitamin D, zinc, iodine and fiber for Czech pregnant women is recommended.

Keywords Nutrition · Resting energy expenditure · Pregnancy

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Introduction

The maternal diet must provide sufficient energy and nutrients to meet the mother's usual requirements, as well as the needs of the growing fetus, and enable the mother to lay down stores of nutrients required for fetal development as well as for lactation [1]. Knowledge of definitive nutritive status can help practicing gynecologists to recommend supplementation in cases of undernutrition to protect against possible pathological changes.

There is an increased requirement during pregnancy for energy and many, but not all, nutrients. Deficiencies can develop because of losses or malabsorption associated with disease, inadequate intake, lack of knowledge about adequate prenatal nutrition or dietary taboos associated with pregnancy [2]. The additional energy requirements of pregnancy result from the development of the products of conception such as fetus and placenta, the growth of existing maternal tissues (breast and uterus), extra maternal fat deposition and tissue synthesis, with consequent increased oxygen consumption [3].

It is frequently asked in gynecological practice which nutrient is low and requires higher intake to decrease the risk of various pathological states during pregnancy and fetus development, and how nutrition contributes to macrosomia of the fetus with the need for Cesarean section. The results of this article are a continuing evaluation in our longitudinal clinical study "NutrPreg" described in a previous article [4] and in which were derived the predictive equations for dietary intake (DI) of energy with substrates as an expression of dietary patterns.

The aim of this article was to evaluate the dietary intake of energy and nutrients (DIEN) of Czech pregnant women and compare it with recommended daily allowances (RDA), because it is currently unknown how these quantities vary with changing body size variables during pregnancy. These results could be applied in clinical practice after confirmation with biomarkers to rectify deficiencies by modification of nutrition if necessary via supplementation.

Methods

Subject characteristics

One hundred and fifty-two healthy pregnant Czech women took part in this longitudinal study. They were randomly recruited from both countryside and city from the Hradec Kralove region. Volunteers represented pregnant women from prenatal courses; they were representative of all socioeconomic and educational background. All women were examined by gynecologists before and during the study. They were nonusers of chronic medications, nonsmokers and nonabusers of alcohol or drugs and had parity $\leq$2. Additional specification for enrollment was that subjects were euthyroid, normoglycemic, and not anemic. The week of pregnancy was taken from gynecological records.

Study design

Anthropometric maternal changes, resting energy expenditure and nutritional assessment were determined throughout pregnancy in four specified periods. Period P1 was from the beginning of pregnancy to 20th week, typical for minimal maternal and fetal development; period P2 was between 21st and 29th weeks, characterized by the beginning of fetal growth and the principal period of synthesis of fat mass; period P3 was defined as between 30th and 36th weeks, with enhanced fetal development; period P4 between 37th and 39th weeks was for the evaluation of the pregnant state just before delivery.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Ethics Committee of Charles University Medical Faculty in Hradec Kralove. Written informed consent was obtained from all subjects.

Determination of resting energy expenditure (REE-IC)

An indirect calorimeter with ventilated hood system (Vmax Series, V6200 Autobox, SensorMedics Corporation, California, USA) was used for the measurement of resting energy expenditure under standard conditions. All subjects were measured after 12 h fasting and had been at rest for 30 min before assessment after arrival from their homes. Before each examination, the instrument was calibrated according to standard procedures for the machine. Subjects were measured in a relaxed, supine position under the canopy hood over a 30-min period, in a room with ambient temperature 21–22 °C and relative humidity 60–80%.

The measured difference between inspired and expired volumes of oxygen and carbon dioxide was adjusted for total urinary nitrogen using the Weir equation to calculate resting energy expenditure in kcal/day (VO_2: oxygen consumption [liters per minute]; CO_2: carbon dioxide production [liters per minute]; TUN: total urinary nitrogen [g/day]) [5]:

$$\text{REE-IC} = ((3940 * \text{VO}_2) + (1106 * \text{VCO}_2)) * 1.44 - 2.17 * \text{TUN} \quad \text{(E1)}$$

Urine was collected during 24 h and stored in the fridge before analysis. Total urinary nitrogen (TUN) was calculated from urinary urea nitrogen (UN in g/day) and weight (W in kg) [6]:

$$\text{TUN} = \text{UN} + 0.03 * \text{W} \quad \text{(E2)}$$

UN content was determined by a standard kinetic UV assay (Roche/Hitachi 917 analyzer) at University Hospital [7] in urine collected over a 24-h period.

Anthropometric measurements

All anthropometric measurements were taken after indirect calorimetry. Height was measured with a stadiometer to the nearest 0.5 cm. Pre-pregnancy body weight was obtained from gynecological documentation. An InnerScan-Body Composition Monitor (Tanita Corporation, Japan) was used for the measurement of body weight (to the nearest 0.1 kg).

Body density was calculated from measurements of three skinfolds (triceps, mid-thigh and supra-ilium) taken with a caliper (Best K-501, Trystom, Czech Republic) by the method of Jackson [8]:

$$\text{BD} = 1.0994921 - (0.0009929 * \text{TTS}) + \left(0.0000023 * \text{TTS}^2\right) - (0.0001392 * \text{A}) \quad \text{(E3)}$$

Body fat mass (FM) was obtained by the method of Raaij validated for pregnancy [9]:

$$10\,\text{weeks}\;\;FM = W/100 * (496.4/BD - 451.6) \quad (E4)$$

$$20\,\text{weeks}\;\;FM = W/100 * (502.2/BD - 458.0) \quad (E5)$$

$$30\,\text{weeks}\;FM = W/100 * (510.8/BD - 476.5) \quad (E6)$$

$$40\,\text{weeks}\;FM = W/100 * (522.5/BD - 480.5) \quad (E7)$$

Body surface area (BSA, in m^2) was calculated by the DuBois equation from height (H) (in cm) and weight W (in kg) [10].

$$BSA = H^{0.725} * W^{0.425} * 0.007184 \quad (E8)$$

Body mass index (BMI in kg m^{-2}) was calculated from weight (W in kg) and height (H in m):

$$BMI = W/H^2 \quad (E9)$$

Ideal body weight (IBW, in kg) for nonpregnant women was calculated from height (H in cm) [11]:

$$IBW = (0.593 * H) - 38.6 \quad (E10)$$

Nutrient assessment

Nutrient assessment was based on self-reported dietary intake records collected during 7 consecutive days. Subjects recorded the type and amount of all food consumed during the previous week before each anthropometric measurement at the hospital. All pregnant women were trained in detail to estimate portion size using scales, measuring spoons and cups. The dietary records were periodically reviewed in the presence of the subjects to resolve any uncertainty in the entries and to assess the completeness of the record. The intake of supplements was not recorded. Professional nutritional software NutriDan (Danone Institut, Benesov, Czech Republic) validated for nutritional assessment was used for the evaluation of dietary records.

RDAs of the Food and Nutrition Board, Institute of Medicine (IOM), National Academies USA were used for the evaluation of nutrient intake [12–18].

Estimated energy requirement (EER, in kcal/day) during pregnancy for each trimester for women 19 years and older was calculated using IOM equations, where PA of 1.16 was applied (physical activity coefficient typical for daily living activities of 30–60 min of moderate daily activity) [19]:

$$EER1 = 354 - (6.91 \times \text{age [y]}) + PA \times [(9.36 \times \text{weight [kg]}) + (726 \text{ vs. height [m]}) \quad (E11)$$
for 1st trimester

$$EER = EER1 + 340 \quad \text{for 2nd trimester} \quad (E12)$$

$$EER = EER1 + 452 \quad \text{for 3rd trimester} \quad (E13)$$

Statistical analysis

The acquired data were analyzed using programs GraphPad Prism5 (GraphPad Software, La Jolla, CA, USA) and Excel 2007 (Microsoft, Redmont, WA, USA). The DIEN was evaluated by descriptive statistics. Two tests were used for the determination of statistical differences between evaluated intake of nutrients and RDA: parametric one-sample *t* test (tt) when data showed normal distribution, and for nonnormal data the nonparametric Wilcoxon signed-rank test (Wt). ANOVA test was performed to determine differences between the four pregnancy periods. Bonferroni test was applied for multiple testing of differences between values from period P1 and each other period. Correlation analysis was applied to demonstrate relationship between DI and anthropometric parameters.

Results

The condition for the enrollment of the women in this study was a physiological course of pregnancy. This was controlled by observations by practicing gynecologists. Table 1 describes the basic characteristics of the participating subjects within the optimal range of delivery and birth parameters, attesting to the physiological outcome of pregnancy. Changes in specific anthropometric parameters as the pregnancy progressed are reported in Table 2.

In our study, we observed a typical course during pregnancy for energy and the majority of nutrients. Minimal intake was observed in period P1 at the beginning of pregnancy, increasing in period P2 to maximum in period P3; in the final period P4, there was a small decrease. Using the Bonferroni test, statistical differences were demonstrated between DIs from period P1 and P3, especially for

Table 1 Descriptive data of 152 pregnant women and fetus parameters on the day of delivery

Pregnant women	
Age (year)	28.9 ± 3.6
Height (cm)	166.7 ± 6.0
Pre-pregnancy BMI	21.1 ± 3.6
Delivery BMI	26.3 ± 3.1
Weight gain	13.47 ± 5.5
Week of delivery	39.6 ± 1.3
Birth parameters	
Birth weight (g)	3,311 ± 423.4
Birth length (cm)	50.4 ± 2.2
Placenta weight (g)	556.3 ± 101.6
Duration of birth (min)	386.9 ± 101.6

Table 2 Anthropometric maternal changes of 152 pregnant women during pregnancy

	P1	P2	P3	P4	ANOVA (*P*)
Week of pregnancy	14.78 ± 5.2	25.55 ± 2.3	32.42 ± 2.1	37.63 ± 0.7	<0.0001
Weight (kg)	61.38 ± 9.8	67.71 ± 8.6	71.66 ± 9.7	73.28 ± 9.7	<0.0001
Weight gain (kg)	3.04 ± 4.3	8.41 ± 3.9	10.85 ± 4.6	13.47 ± 5.5	<0.0001
W-IBW (kg)	1.51 ± 9.3	7.04 ± 8.1	11.60 ± 9.1	13.00 ± 8.7	<0.0001
BMI (kg/m^2)	22.27 ± 3.4	24.21 ± 3.0	25.90 ± 3.4	26.32 ± 3.1	<0.0001
BSA (m$^{2)}$	1.64 ± 0.1	1.76 ± 0.1	1.79 ± 0.1	1.82 ± 0.1	<0.0001
S triceps (mm)	14.88 ± 5.5	16.31 ± 4.4	18.98 ± 5.3	20.05 ± 6.5	0.0034
S mid-thigh (mm)	24.35 ± 7.6	25.20 ± 6.5	29.35 ± 8.8	34.28 ± 8.9	0.0044
S suprailiac (mm)	16.59 ± 7.1	19.18 ± 5.8	22.56 ± 8.2	19.92 ± 6.9	0.0017
Fat mass (kg)	13.59 ± 5.8	14.73 ± 4.6	17.07 ± 5.7	17.85 ± 6.7	<0.0001
Free-fat mass (kg)	47.79 ± 5.1	52.98 ± 6.0	54.59 ± 6.7	55.43 ± 5.8	<0.0001
REE-IC (kcal/day)	1,453 ± 172	1,550 ± 173	1,617 ± 204	1,661 ± 209	<0.0001

Values given are the mean ± standard deviation

P1–P4, period of pregnancy, *S-x* skinfolds, *n* number of assessments, *REE-IC* measured resting energy expenditure by indirect calorimetry

energy, nutritive substrates, MUFA, PUFA, cholesterol and phosphates. This pattern was found for all nutrients and energy intakes, with the exception of carbohydrates and sugar. This trend was also observed for phosphates, iron and selenium in the minerals group and for α-tocopherol and niacin in the vitamins group. DI of other nutrients during pregnancy was uniform with no statistical differences. Statistically significant differences during the whole pregnancy were shown by ANOVA test (Table 3).

All DIs were compared with RDA and evaluated against the requirement for pregnant women. Statistically significant lower intakes were found for energy, fiber, water, potassium, iron, fluoride, cholecalciferol, α-tocopherol and folate in all periods of pregnancy; intake of zinc was lower in periods P1, P2 and P4 only. RDAs for DIEN of energy were calculated using Eqs. E11–E13, and the values obtained for each period were P1 2,153 kcal/day, P2 2,560 kcal/day, P3 2,713 kcal/day and P4 2,730 kcal/day.

In contrast, intake was observed to be statistically significantly elevated over RDA in the case of carbohydrates throughout the pregnancy and for proteins in period P3 only. DI of proteins on average during pregnancy was 14.45 ± 0.3%; fats, 32.85 ± 1%; and carbohydrates, 52.50 ± 1%. DI of PUFA (5.7 ± 0.4%) was lower than the RDA of 10% of total energy intake (Table 3).

Substances whose intake exceeded RDA but did not exceed the tolerable upper limit (UL) were the minerals phosphate, copper and selenium, and the vitamins retinol, riboflavin, niacin and L-ascorbic acid. Sodium exceeded the UL of 2.3 g/day in all periods of pregnancy (Table 4).

Correlation analysis was used to evaluate the relationships between anthropometric parameters and DI expressed per kg body weight. Except for copper and fluoride, positive correlations (Tables 5, 6) were demonstrated between measured REE/kg and intake of energy, substrates and minerals, but in the case of vitamins, positive correlation was observed only for niacin. Negative correlations were observed between all measured anthropometric parameters and DI per kg body weight, that is, there was decrease in DI/kg with increase in body parameters.

Discussion

In this study, several anomalies were discovered between determined DIED and RDA in relation to anthropometric parameters.

Evaluation of DI of energy compared to RDA as predicted from Eqs. E11–E13 showed low saturation of pregnant women during gestation. To verify this result, we calculated estimated total energy expenditure (TEE) requirement of pregnant women in this study by application of the knowledge that REE measured by indirect calorimetry is 61.5% of TEE. This value was obtained from analysis of three European studies with similar measured REE and phases of pregnancy [20–22]. TEE estimated in this way were for period P1, 2,362 kcal/day; P2, 2,520 kcal/day; P3, 2,629 kcal/day; and P4, 2,700 kcal/day, closer to RDA predicted from E11–E13. Daily nutritional energetic intakes of women during pregnancy expressed as ratio DEI/TEE were 0.84 ± 0.19 in the first period P1, 0.82 ± 0.16 in P2, 0.86 ± 0.18 in P3 and 0.77 ± 0.14 in the last period P4. Correlation analysis between REE, anthropometric parameters and DI demonstrated that the nutritional demand of women during gestation is based on the requirement to maintain homeostasis during pregnancy, which is important for fetal development. The positive correlation between REE and DI indicates that an increase

Table 3 Nutritive intake of energy and macronutrients during pregnancy

	RDA	P1	% RDA	P2	% RDA	P3	% RDA	P4	% RDA	ANOVA *P*
Energy (Kcal)	E 11–13	1,983.0 ± 436.9	92.1*	2,074.0 ± 413.1	81.0**	2,251.0 ± 479.0	83.0**	2,069.0 ± 364.6	75.8**	0.02
Protein (g)	71	71.0 ± 14.6	100.0	75.7 ± 15.6	106.6*	80.6 ± 16.7	113.6**	72.3 ± 11.2	101.9	0.01
Fat (g)	ND	68.8 ± 19.1		72.9 ± 16.5		83.7 ± 31.0		74.3 ± 15.8		0.01
SFA	ND	28.9 ± 8.1		30.1 ± 7.3		33.8 ± 9.9		30.6 ± 7.5		0.03
MUFA (g)	ND	20.6 ± 5.9		21.6 ± 5.3		25.6 ± 11.0		22.6 ± 4.9		0.01
PUFA (g)	ND	11.4 ± 4.6		12.8 ± 3.9		15.1 ± 9.0		12.8 ± 3.7		0.03
Cholesterol (mg)	ND	293.3 ± 96.1		313.5 ± 105.4		351.5 ± 102.1		328.6 ± 85.3		0.04
Carbohydrates (g)	175	258.3 ± 61.3	147.6**	267.3 ± 64.2	152.7**	280.9 ± 58.6	160.5**	266.2 ± 55.6	152.1**	0.35
Sugars (g)	ND	91.1 ± 37.4		92.1 ± 39.4		98.2 ± 33.1		98.9 ± 41.3		0.67
Starch (g)	ND	143.5 ± 28.9		149.9 ± 35.9		156.0 ± 33.6		141.7 ± 23.1		0.11
Fiber (g)	28	20.4 ± 3.8	72.9**	22.6 ± 5.3	80.6**	23.7 ± 6.3	84.8**	22.3 ± 5.1	79.7**	0.05
Water (ml)	3,000	2,345.0 ± 1,126.0	78.2*	2,113.0 ± 914.7	70.4**	2,472.0 ± 795.5	82.4**	2,581.0 ± 1,031.0	86.0*	0.06

Values given are the mean ± standard deviation

ND not determinable; * $P = 0.0001$–0.05 of statistical significant difference between DI of nutrient and RDA (via tt or Wt), ** $P < 0.0001$

in REE due to increased body size results in increased DIEN. A very good indicator for increase in DI was found to be the difference between body weight and ideal body weight (W-IBW), which is a better measure of the requirement for nutrients than simple weight gain; it was consequently used in a previous article [4] for the derivation of equations for the prediction of DI of energy and substrates. This parameter is a more sensitive marker of the DI requirement of the pregnant body throughout gestation. For women with lower BMI and lower contents of fat mass, we have shown that the higher difference W-IBW was consistent with increased DI of energy and substrates ($r = -0.41$, $P < 0.0001$) necessary for the synthesis of adequate tissue deposits and fetal development. This demonstrated relationship is in line with the recommendation of IOM that pregnant women with lower BMI should gain more weight, with consequently higher DI.

Some studies have recommended supplementation of cyanocobalamin and some other B-group vitamins during pregnancy [23]. In this study, we did not confirm lower DI of these nutrients (except for folate). Because DI of cyanocobalamin was on average double the RDA, we cannot advocate its supplementation.

We also demonstrated low intake of some nutrients. Well-known lower DI of folate and iron were observed; however, these were expected according to other studies. A low consumption of folate of around 40% of RDA was found, which is a serious risk factor especially during the periconceptional period for developmental disorders such as spina bifida. This is associated with preterm delivery, infant low birth weight and fetal growth retardation [24]. Also found was a low intake of iron in the range 52–60% of RDA, known to be a very common deficiency in pregnancy, and manifested in clinical practice by hematological parameters that contribute to anemia or premature delivery [25].

Although several lower DI below RDA were observed in this study, all the pregnant women and fetal development were well-controlled by practicing gynecologists, with good pregnancy outcome. During their pregnancy, most of the women received preventive supplementation of folic acid and also iron in cases where low hemoglobin levels were measured.

Typical for Czech pregnant women was an overabundant DI of sodium which was more than twice RDA, in spite of the practical recommendation to decrease salt consumption and increase DI of potassium-rich foods, to minimize edema and hypertension. Although the increased DI of sodium was principally from salt, the intake of iodine was observed to be well below RDA.

A study by Zimmermann [26] concluded that in countries with successful sustained iodized salt programs, the iodine status of mothers and their infants is adequate. We

Table 4 Nutritive intake of minerals and vitamins during pregnancy

	RDA	P1	% RDA	P2	% RDA	P3	% RDA	P4	% RDA	ANOVA *P*
Sodium (mg)	1,500	3,996.0 ± 1,019.0	266.4**	4,249.0 ± 1,178.0	283.3**	4,312.0 ± 874.3	287.5**	4,023.0 ± 750.1	268.2**	0.31
Potassium (mg)	4,700	3,373.0 ± 1,105.0	71.8**	3,655.0 ± 1,095.0	77.8**	3,854.0 ± 1,189.0	82.0**	3,810.0 ± 1,106.0	81.1**	0.23
Calcium (mg)	1,000	951.8 ± 307.4	95.2	979.6 ± 312.7	98.0	1,073.0 ± 304.8	107.3	1,035.0 ± 269.6	103.5	0.21
Magnesium (mg)	350	382.4 ± 104.4	109.3	394.3 ± 94.4	112.7*	427.4 ± 91.3	122.1**	420.9 ± 98.8	120.3**	0.09
Phosphate (mg)	700	1,557.0 ± 370.8	222.4**	1,640.0 ± 391.0	234.3**	1,787.0 ± 390.5	255.3**	1,636.0 ± 395.4	233.7**	0.04
Iron (mg)	27	14.0 ± 3.5	52.0**	15.3 ± 3.5	56.7**	16.3 ± 3.5	60.4**	15.8 ± 4.1	58.6**	0.04
Zinc (mg)	11	9.6 ± 2.2	87.0*	10.1 ± 2.3	92.2*	10.7 ± 2.3	97.1	10.0 ± 1.7	90.6*	0.11
Copper (mg)	1	1.7 ± 0.4	168.4**	2.1 ± 2.6	209.2**	1.9 ± 0.4	185.7**	1.8 ± 0.5	181.3**	0.61
Selenium (μg)	60	63.1 ± 19.6	105.2	75.4 ± 23.7	125.6**	80.2 ± 31.8	133.6**	75.2 ± 19.9	125.3**	0.02
Fluoride (μg)	3,000	872.8 ± 327.6	29.1**	852.0 ± 311.9	28.4**	978.3 ± 367.6	32.6**	967.3 ± 384.9	32.2**	0.15
Iodine (μg)	220	82.0 ± 31.1	37.3**	90.3 ± 44.2	41.0**	99.1 ± 55.5	45.0**	89.3 ± 36.7	40.6**	0.36
Retinol (μg)	770	844.0 ± 1,085.0	109.6	896.0 ± 1,170.0	116.4*	1,227.0 ± 1,597.0	159.4**	1,631.0 ± 2,148.0	211.8**	0.06
Carotenes (μg)	ND	2,541.0 ± 1,503.0		2,898.0 ± 1,532.0		3,254.0 ± 1,837.0		3,385.0 ± 2,294.0		0.16
Cholecalciferol (μg)	5	2.8 ± 2.3	56.2**	3.9 ± 4.8	78.8**	3.5 ± 3.2	70.4**	2.5 ± 2.6	50.5**	0.19
Tocopherol (mg)	15	9.5 ± 4.4	63.5**	11.1 ± 3.8	73.7**	12.2 ± 4.7	81.5**	11.2 ± 3.8	74.8**	0.04
Thiamin (mg)	1.4	1.5 ± 0.5	109.2	1.7 ± 0.5	124.4**	1.7 ± 0.4	123.5**	1.8 ± 0.4	125.9**	0.11
Riboflavin (mg)	1.4	1.6 ± 0.7	115.6*	1.8 ± 0.6	127.3**	1.9 ± 0.6	134.5**	1.9 ± 0.5	136.6**	0.15
Niacin (mg)	18	28.5 ± 8.0	158.2**	31.0 ± 7.5	172.2**	33.4 ± 8.4	185.7**	31.4 ± 6.4	174.2**	0.03
Pyridoxine (mg)	1.9	1.9 ± 0.6	101.4	2.2 ± 0.6	116.7*	2.2 ± 0.6	118.3**	2.3 ± 0.6	122.1*	0.04
Cyanocobalamin (μg)	2.6	6.1 ± 2.9	232.8**	7.3 ± 3.9	281.6**	7.6 ± 3.4	291.6**	8.1 ± 3.6	312.7**	0.08
Folate (μg)	600	238.9 ± 95.9	39.8**	262.1 ± 93.9	43.7**	271.3 ± 84.8	45.2**	280.2 ± 89.9	46.7**	0.24
L-ascorbic acid (mg)	85	164.6 ± 92.1	193.6**	199.4 ± 113.1	234.6**	188.5 ± 76.4	221.8**	210.8 ± 99.2	248.0**	0.20

Values given are the mean ± standard deviation

ND not determinable; * $P = 0.0001–0.05$ of statistical significant difference between DI of nutrient and RDA (via tt or Wt), ** $P < 0.0001$

Table 5 Correlation between anthropometric parameters and intakes of energy with macronutrients during pregnancy

Intakes/kg	REE/kg	REE/BSA	W	prep W	WG	W-IBW	H	FM	FFM	BMI	BSA	prep BMI
Energy	0.3**	−0.15*	−0.46**	−0.41**	−0.24*	−0.46**	−0.1	−0.35**	−0.4**	−0.44**	−0.41**	−0.39**
Proteins	0.34**	−0.09	−0.48**	−0.45**	−0.23*	−0.45**	−0.18*	−0.36**	−0.41**	−0.42**	−0.46**	−0.38**
Fat	0.23*	−0.08	−0.32**	−0.33**	−0.11	−0.32**	−0.08	−0.23*	−0.3**	−0.3**	−0.29**	−0.32**
SFA	0.26*	−0.1	−0.38**	−0.36**	−0.16*	−0.35**	−0.15*	−0.27**	−0.34**	−0.33**	−0.36**	−0.31**
MUFA	0.21*	−0.06	−0.28**	−0.3**	−0.08	−0.28**	−0.08	−0.18*	−0.27*	−0.26*	−0.26**	−0.29**
PUFA	0.14	−0.05	−0.17*	−0.19*	−0.04	−0.2*	0.03	−0.13	−0.15*	−0.2*	−0.13	−0.23*
Cholesterol	0.24*	−0.04	−0.33**	−0.33**	−0.11	−0.29**	−0.15*	−0.23**	−0.3**	−0.26*	−0.33**	−0.27*
Carbohydrates	0.28**	−0.14	−0.43**	−0.38**	−0.23*	−0.43**	−0.07	−0.34**	−0.35**	−0.42**	−0.38**	−0.37**
Sugars	0.15*	−0.05	−0.19*	−0.2*	−0.06	−0.21*	0.02	−0.14	−0.16*	−0.22*	−0.15*	−0.23*
Starch	0.29**	−0.21*	−0.51**	−0.41**	−0.32**	−0.51**	−0.09	−0.42**	−0.4**	−0.5**	−0.44**	−0.4**
Fiber	0.27*	−0.16*	−0.39**	−0.37**	−0.17*	−0.44**	0.04	−0.34**	−0.29**	−0.44**	−0.31**	−0.43**

Correlation expressed as Pearson coefficient r

prep W pre-pregnancy weight, *prep BMI* pre-pregnancy BMI; * $P = 0.0001–0.05$; ** $P < 0.0001$

cannot confirm this in the case of Czech pregnant women, because our study observed an iodine nutritional low intake in the range 37–45% of RDA. Because iodine deficiency may lead to inadequate thyroid hormone production with its consequences of disastrous effects on fetal neurodevelopment [27, 28], it is essential to assess urinary iodine, serum thyroxine and thyroid-stimulating hormone as biomarkers of iodine deficiency [29].

Nutritional assessment showed low DI of vitamin D in the range 56–79% of RDA. Deficiencies of vitamin D are associated with multiple adverse health outcomes in mother and neonates [30]. Risk is increased when DI is low, and there is increased skin pigmentation, or customs of dress or behavior are followed that reduce sunlight exposure. Accordingly, higher intake of vitamin D for pregnant women is recommended.

Lower DI below RDA was also observed in intake of PUFA and food content with n-3 and n-6 fatty acids. Enhanced consumption of fish products or administration in the form of a supplement could have positive effects on prolonging gestation and possibly enhancing infant neurodevelopment [31]. Lower consumption of dietary fiber was also found which may contribute to the constipation which is such a typical problem for many pregnant women.

DI of retinol was seen to be higher than RDA. Estimation of the overall intake of vitamin A as the sum of retinol and carotenoids (expressed in terms of retinol) gave values for period P1, 1,056 μg/day; P2, 1,469 μg/day; P3, 1,868 μg/day; and P4, 1,913 μg/day, which did not exceed the UL of 3,000 μg/day ($P < 0.0001$). Vitamin A deficiency is strongly associated with depressed immune function and higher morbidity and mortality due to various infectious diseases [32] and is an essential nutrient in pregnancy. Supplementation may be recommended on a case-by-case basis, but was not necessary in this study; since intake did not exceed the UL, neither was there risk of malformation during embryonic development.

Some study limitations need to be addressed

In this study, several significant differences between DIEN and RDA were demonstrated. Some cases were serious although all pregnant women were in the physiological state with good pregnancy outcome thanks to preventive supplementation, as in the case of iron and folic acid. In order to prevent distortion of the data, intake of supplements was not included in the evaluation, because some pregnant women recorded irregular intake.

Nutritive assessment was conducted using the sophisticated program NutriDan via a 7-day nutritional self-assessed record. This study was based on knowledge from other studies which indicated that repeated 24-h dietary recall is reliable enough for large-scale field studies in pregnancy and remains the best available dietary measurement tool for such research [33–36]. Fidelity was improved in our study by replacement of 24-h recall with a 7-day record, with training of the subjects in estimation and some actual weighing of food portions. The reliability of the results reflects the accuracy of the program for the estimation of the composition of recorded food items.

This article is a nutritional assessment in relation to anthropometric parameters, with the aim of learning how to prevent pathological outcomes by modification of nutrition or alternatively supplementation; however, deficiencies were not evaluated because due to the general complexity of this study, it was not possible to ensure examination of special biomarkers in plasma or urine. Although this study was performed with high attention to precision, it may be

Table 6 Correlation between anthropometric parameters and intakes of minerals with vitamins during pregnancy

Intakes/kg	REE/kg	REE/ BSA	W	prep W	WG	W-IBW	H	FM	FFM	BMI	BSA	prep BMI
Water	0.05	−0.18*	−0.21*	−0.16*	−0.15*	−0.21*	−0.04	−0.09	−0.24*	−0.21*	−0.19*	−0.15*
Sodium	0.21*	−0.19*	−0.45**	−0.42**	−0.21*	−0.41**	−0.19*	−0.31**	−0.41**	−0.38**	−0.43**	−0.34**
Potassium	0.22*	−0.06	−0.29**	−0.25*	−0.16*	−0.28**	−0.08	−0.23*	−0.24*	−0.27*	−0.26*	−0.23*
Calcium	0.23*	−0.13	−0.38**	−0.37**	−0.16*	−0.36**	−0.15*	−0.28**	−0.34**	−0.33**	−0.37**	−0.32**
Magnesium	0.25*	−0.15*	−0.4**	−0.35**	−0.21*	−0.4**	−0.08	−0.31**	−0.34**	−0.39**	−0.36**	−0.34**
Phosphates	0.28**	−0.12	−0.42**	−0.39**	−0.2*	−0.4**	−0.14	−0.32**	−0.37**	−0.38**	−0.4**	−0.35**
Iron	0.21*	−0.13	−0.34**	−0.32**	−0.14	−0.36**	−0.01	−0.27*	−0.27*	−0.35**	−0.28**	−0.34**
Zinc	0.3**	−0.16*	−0.49**	−0.47**	−0.21*	−0.47**	−0.16*	−0.39**	−0.41**	−0.44**	−0.46**	−0.42**
Copper	0.07	−0.07	−0.2*	−0.22*	−0.04	−0.13	−0.2*	−0.13	−0.19*	−0.11	−0.23*	−0.13
Selenium	0.33**	0.05	−0.31**	−0.3**	−0.12	−0.28**	−0.14	−0.26*	−0.25*	−0.26*	−0.3*	−0.26*
Fluoride	0.1	−0.14	−0.22*	−0.22*	−0.08	−0.24*	0.01	−0.13	−0.22*	−0.24*	−0.18*	−0.24*
Iodine	0.15*	−0.05	−0.2*	−0.21*	−0.07	−0.22*	−0.02	−0.14	−0.19*	−0.21*	−0.17*	−0.22*
Retinol	−0.03	0.02	0.01	−0.04	0.07	0.03	−0.04	0	0.02	0.05	−0.01	0
Carotenes	0.05	−0.13	−0.13	−0.22*	0.07	−0.2*	0.14	−0.14	−0.08	−0.21*	−0.07	−0.32**
Cholecalciferol	0.06	−0.05	−0.14	−0.2*	0.02	−0.14	−0.04	−0.1	−0.13	−0.13	−0.13	−0.2*
Tocopherol	−0.04	−0.14	−0.04	−0.13	0.1	−0.1	0.13	−0.06	−0.01	−0.11	0.01	−0.21*
Thiamin	0.11	−0.07	−0.21*	−0.25*	−0.02	−0.19*	−0.1	−0.21*	−0.14	−0.18*	−0.21*	−0.21*
Riboflavin	0.09	−0.09	−0.22*	−0.31**	0.04	−0.19*	−0.1	−0.18*	−0.17*	−0.17*	−0.22*	−0.27*
Niacin	0.19*	−0.07	−0.28**	−0.33**	−0.04	−0.27*	−0.08	−0.23*	−0.22*	−0.26*	−0.26*	−0.31**
Pyridoxine	0.09	−0.09	−0.19*	−0.27*	0.05	−0.18*	−0.03	−0.18*	−0.13	−0.19*	−0.16*	−0.27*
Cyanocobalamin	0.02	−0.04	−0.11	−0.18*	0.04	−0.06	−0.15*	−0.08	−0.1	−0.03	−0.15*	−0.09
Folate	0.07	−0.08	−0.16*	−0.22*	0.03	−0.17*	0.02	−0.17*	−0.08	−0.17*	−0.12	−0.24*
Ascorbic acid	0.05	0.02	−0.02	−0.08	0.08	−0.05	0.09	−0.05	0.02	−0.07	0.02	−0.14*

Correlation expressed as Pearson coefficient *r*

prep W pre-pregnancy weight, *prep BMI* pre-pregnancy BMI; * $P = 0.0001$–0.05; ** $P < 0.0001$

necessary in other studies to use specific biomarkers to confirm deficiencies or overnutrition.

Only pregnant healthy Czech women with pre-pregnancy BMI in the range from 17.5 to 24.7 kg/m^2 were recruited into this study. Although we can reasonably expect different DIs of pregnant women in other countries with different dietary habits, it may be that the DIs are similar when assessed against anthropometric parameters.

Conclusion

This study revealed lower DI of energy and intakes of some nutrients relative to the corresponding RDA during pregnancy of Czech women. Evaluated DIEN corresponded with body size variables, especially with W-IBW. According to current knowledge on prevention of various pathological states, modification of food intake or alternatively supplementation is recommended, for folic acid, iron, vitamin D, zinc, iodine and fiber.

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