Assessment of protein intake during pregnancy using a food frequency questionnaire and the effect on postpartum body weight variation

Avaliação do consumo de proteína durante a gestação, com questionário de freqüência e seu efeito na mudança de peso materno no pós-parto

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Abstract

The aim of this study was to investigate the effect of protein intake during pregnancy on postpartum weight variation. This was a prospective cohort study with 421 women interviewed at 15 days (baseline) and 2, 6, and 9 months postpartum. Data on diet were obtained using the food frequency questionnaire, focusing on the second and third trimesters. Protein intake was considered adequate when women consumed ≥ 1.2g of protein per kg body weight, and inadequate when < 1.2g/kg. The study adopted the mixed effects model for repeated measurements over time. The results showed a mean postpartum weight loss of 0.409kg/month (±0.12) (p < 0.01). Women with adequate protein intake during pregnancy lost an additional 0.094kg/month (±0.04) during postpartum (p = 0.03) when compared to women with inadequate intake. The model was adjusted for energy, % body fat, stature, age, schooling, skin color, and smoking. Recommended protein intake during pregnancy favored postpartum weight reduction.

Proteins; Postpartum Period; Body Weight

Introduction

In the 1980s and 90s, the World Health Organization (WHO) recommended daily protein intake of 0.91g per kg of body weight (PR/kg) [1]. This daily recommendation represented 10% to 15% of the total diet energy. The current protein intake recommendation by the Institute of Medicine [2] is 1.1PR/kg for pregnant women. Although there is no solid evidence on variability for recommended protein intake, the Institute of Medicine [2] estimates that it can vary from 10% to 35%.

Research on protein intake is limited, especially during pregnancy, given the limited knowledge on the long-term consequences of high-protein diets. Pregnancy is almost always considered an exclusion criterion for clinical trials on the theme [3,4].

In addition, the validity of measuring protein in nutritional epidemiology studies is still a controversial issue [5]. Although numerous validation studies for the food frequency questionnaire (FFQ) have shown that this instrument is adequate for measuring dietary consumption of foods and nutrients [6,7], including proteins [8,9,10,11], some authors question its validity [5]. Also, observations during pregnancy include the possibility of overestimating the consumption of healthy foods [12], variability in consumption at different moments in pregnancy, and some modifications associated with intolerance or eating compul-

sions resulting from the physiological state of pregnancy [13].

Evaluation of protein intake in pregnant and lactating women can aim not only at adjusting nutrition to the special requirements of pregnancy and breastfeeding, but also to avoid postpartum weight retention. In a recent study, Castro et al. [14] showed that protein intake greater than or equal to 1.2PR/kg favored postpartum weight loss. A clinical trial by Lovelady et al. [15] used 20% recommended protein in the intervention group to evaluate weight loss in breastfeeding women with overweight. At the end of follow-up, this group had lost more weight and had a diet with 18% protein, while the control group's diet showed 15% protein.

Thus, the aim of the current study was to investigate the effect of protein intake during pregnancy on postpartum weight variation. The underlying hypothesis was that high-protein diet favors weight loss.

Material and methods

Study design and sample

The current study reports on a prospective cohort of women interviewed at approximately 15 days (baseline) and 2, 6, and 9 months postpartum. Data were collected at the Marcolino Candau Municipal Health Center in the city of Rio de Janeiro, Brazil, from May 1999 to April 2001. The study involved 15 months of recruitment and nine months of follow-up. Further details on the methods and inclusion and exclusion criteria have been published elsewhere [16,17].

Among the 709 women invited to participate in the study, 479 agreed to participate. The following were excluded from the analyses: 47 women younger than 18 years of age and two women with energy intake during pregnancy greater than 6,000kcal [18]. Of the total of 430 women (100%) included at baseline, 380 (88.4%), 311 (72.3%), and 283 (65.8%) were present at 2, 6, and 9 months postpartum, respectively. Previously published analyses showed a random pattern of losses for all the variables except age [19] and beer and liquor consumption [18]. The study was approved by the Institutional Review Board of the Nucleus for Studies in Collective Health (NESC) at the Federal University in Rio de Janeiro (UFRJ). All the study's stages were announced to the participants, who signed a free and informed consent form.

Exposures and outcome

Information on diet was obtained retrospectively using the FFQ validated by Sichieri [20], during the first follow-up visit, at 15 days postpartum. The reference period for food intake pertained to the last six months of pregnancy. Intake levels for total energy, protein, and protein foods (eggs, meat, chicken, fish, milk, and beans) were calculated using a program developed in SAS, version 8.2 (SAS Inst., Cary, USA). Table 1 describes protein and protein food inake: (i) in grams; (ii) intake density (nutrients and foods in grams divided by energy intake).

The variable "protein in g per kg body weight per day" (PR/kg) refers to intake during pregnancy as measured at 15 days postpartum, when 421 women (98%) answered the FFQ. Calculation was based on total protein intake divided by weight measured at baseline [total protein (g) at baseline/weight (kg) at baseline]. The variable PR/kg was analyzed as a fixed measurement in time.

Based on the current protein intake recommendation of 1.1PR/kg for pregnant women [2], the study adopted a cutoff point of 1.2PR/kg. This cutoff was used to distinguish women according to high and low dietary protein levels, as in a previous study [14]. Adequate protein intake was defined as ≥ 1.2PR/kg. Women with PR/kg intake below the cutoff point were defined as having inadequate protein intake.

Weight was measured at all four visits with a digital scale (model PL 150; Filizola São Paulo, Brazil) with a capacity of 150kg, accurate to 0.1kg. Participants were weighed barefoot and wearing light clothing. Weight was considered a continuous variable with time-dependent measurement.

Co-variables

The following information was obtained at baseline: anthropometric [pre-gestational weight (kg), stature (cm), and body fat (%)]; socio-demographic [family income (in Brazilian *Reais*), marital status (married/common-law marriage versus single), and skin color (white, brown, or black)]; and lifestyle [smoking (smokers versus non-smokers)]. All the anthropometric measurements were obtained according to the methodology described by Lohman et al. [21]. Stature was measured with 0.1 cm accuracy using an anthropometer (Harpenden Inc., UK). Body fat percentage was estimated using bioimpedance (BIA 101Q; RJL Inc., USA). Pre-gestational body mass index (BMI) was calculated using the pre-gestational weight reported at the first interview at 15 days postpartum. At two and

Table 1

Mean and standard deviation (SD) for protein food intake (g) and intake density (g/kcal) among 421 women with adequate * versus inadequate ** protein intake per kg body weight (PR/kg) during pregnancy.

Variables	Protein and protein food intake					
	Adequate intake Mean (SD)	Gram Inadequate intake Mean (SD)	p-value ***	Adequate intake Mean (SD)	Density Inadequate intake Mean (SD)	p-value ***
Energy (kcal)	3,263 (766)	2,263 (549)	< 0.01	32.6 (0.77)	22.6 (0.55)	< 0.01
Protein (g)	101.6 (24.2)	64.4 (13.4)	< 0.01	31.4 (4.20)	29.0 (4.58)	< 0.01
PR/kg (g/kg)	1.74 (0.50)	0.96 (0.17)	< 0.01	0.54 (0.12)	0.44 (0.09)	< 0.01
Eggs (number)	0.38 (0.39)	0.22 (0.31)	< 0.01	0.12 (0.12)	0.10 (0.15)	0.16
Chicken (pieces)	0.85 (0.72)	0.46 (0.38)	< 0.01	0.27 (0.22)	0.22 (0.22)	0.02
Meat (slices)	1.01 (0.58)	0.65 (0.43)	< 0.01	0.31 (0.16)	0.29 (0.20)	0.31
Fish (filets)	0.30 (0.56)	0.16 (0.22)	< 0.01	0.09 (0.10)	0.07 (0.11)	0.21
Milk (glasses)	2.16 (1.66)	1.95 (1.44)	0.15	0.68 (0.53)	0.90 (0.73)	< 0.01
Beans (servings)	2.30 (1.31)	15.8 (0.92)	< 0.01	0.74 (0.47)	0.74 (0.47)	0.95

* Adequate protein intake: PR/kg ≥ 1.2g/kg;

** Inadequate protein intake: PR/kg < 1.2g/kg;

*** Student's t test.

six months follow-up, information was collected on schooling (in years) and parity (primiparous or multiparous), while the variable "total days of predominant breastfeeding" [22] was recorded at all of the visits. The leisure-time physical activity score was estimated at all of the visits, based on the questionnaire developed by Shapiro et al. [23].

Data analysis

The study used the mixed effects model for repeated measurements over time [24,25] to assess postpartum weight change as a function of PR/kg intake (Figure 1). The analyses were done in the *Proc Mixed* program, SAS version 8.2. Further details on the modeling process can be found in Castro et al. [14].

Briefly, the study considered as potential confounding factors the variables from the theoretical causal model, constructed *a priori* (Figure 2), that were associated ($p \leq 0.20$) with the outcome variable (weight in kg) and the explanatory variable (protein in g). Weight and protein intake in grams were distributed across the various quartiles: income, schooling, pre-gestational BMI, energy, leisure-time physical activity score, stature, percentage body fat, and total days of predominant breastfeeding. The other variables were categorized as follows: age (≥ 30, < 30 years), marital status (single versus married or common-law marriage), skin color (white, brown, black), parity (primiparous, multiparous), and smoking (smoker versus non-smoker).

In the modeling of repeated measures over time, models A and B are referred to respectively as the unconditional means model and the unconditional growth model. Model C included only the time variable and the predictive variables for weight variation (protein per kg of body weight as a dichotomous variable and its interaction with time). Model D included the variables energy, stature, and percentage body fat at baseline, which were considered confounding factors. As described previously [14], the age and skin color variables were introduced into model E because the women with adequate intake were younger and included a higher proportion of brown-skinned women ($p < 0.05$). The variables smoking ($p = 0.06$) and schooling ($p = 0.08$) were added because they displayed a borderline distribution ($p < 0.10$) at baseline between the groups with adequate and inadequate intake [14]. All these variables were inserted alone and with their interaction with time. Model F was then adjusted for the variables energy, percentage body fat, and stature at baseline and for age, schooling, smoking, and their interactions with time and skin color. Only the interaction variable skin color*time was excluded. In this final model, except for the variables smoking ($p = 0.53$) and years of schooling ($p = 0.17$), all the others and their respective interactions with time were significantly associated with the outcome ($p < 0.05$).

Figure 1

Stages in the repeated measurements (over time) model.

i) Model A: unconditional means model that describes and quantifies the variation in the outcome (weight) at each level.

- $\{Y_{ij} = \gamma00 + (\varepsilon_{ij} + \zeta00_i)\}$;

ii) Model B: unconditional growth model that introduces the predictive variable time.

- $\{Y_{ij} = \gamma00 + \gamma10Time_{ij} + (\varepsilon_{ij} + \zeta0_i)\}$;

iii) Model C: conditional model that includes the explanatory variable PR/kg and its interaction with time.

- $\{Y_{ij} = [\gamma00 + \gamma01PR/kg_i] + [\gamma10Time_{ij} + \gamma11\ PR/kg_i\ (Time_{ij})] + [(\varepsilon_{ij} + \zeta0_i)]\}$;

iv) Model D: conditional model adjusted for the confounding factors energy, % body fat (% BF), and stature at baseline.

- $\{Y_{ij} = [\gamma00 + \gamma01PR/Kg_i + \gamma02Energy_i + \gamma03\%BF_i\ \gamma04Stature_i] + [\gamma10Time_{ij} + \gamma11\ PR/kg_i\ (Time_{ij})] + [(\varepsilon_{ij} + \zeta0_i)]\}$;

v) Model E: conditional model D controlled for the variables: age, skin color, smoking, schooling, and interactions with time. These variables differed between the two groups of women at baseline ($p \leq 0.10$).

- $\{Y_{ij} = [\gamma00 + \gamma01PR/kg_i + \gamma02Energy_i + \gamma03\%BF_i\ \gamma04Stature_i + \gamma05Age_i + \gamma06Skin\ color_i + \gamma07Smoking_i + \gamma08Schooling_i] + [\gamma10Time_{ij} + \gamma11PR/Kg_i$
($Time_{ij}$) $+ \gamma15Age_i\ (Time_{ij}) + \gamma16Skin\ color_i\ (Time_{ij}) + \gamma17Smoking_i\ (Time_{ij}) + \gamma18Schooling\ (Time_{ij})] + [(\varepsilon_{ij} + \zeta0_i)]\}$;

vi) Model F: final conditional model: exclusion of the interaction variable skin color * time ($p = 0.14$) since it did not show a significant association with the outcome.

- $\{Y_{ij} = [\gamma00 + \gamma01PR/kg_i + \gamma02Energy_i + \gamma03\%BF_i\ \gamma04Stature_i + \gamma05Age_i + \gamma06Skin\ color_i + \gamma07Smoking_i + \gamma08Schooling_i] + [\gamma10Time_{ij} + \gamma11PR/kg_i$
($Time_{ij}$) $+ \gamma15Age_i\ (Time_{ij}) + \gamma17Smoking_i\ (Time_{ij}) + \gamma18Schooling\ (Time_{ij}) + [(\varepsilon_{ij} + \zeta0_i)]\}$;

Findings

Total energy intake was 3,263kcal (±766kcal) and 2,263 kcal (±549kcal), respectively, for women with adequate and inadequate PR/kg intake, according to the Institute of Medicine recommendations [2] (Table 1). Mean intake was 1.74PR/kg (±0.50) among pregnant women with adequate intake and 0.96PR/kg (±0.17) for those with inadequate intake.

The findings in Table 1 show that pregnant women with intake ≥ 1.2PR/kg showed quantitatively higher intake of all the protein foods analyzed ($p < 0.01$) except for milk ($p = 0.15$). As for dietary density, all the pregnant women with adequate intake showed qualitatively higher protein intake for gram weight ($p < 0.01$), PR/kg, and chicken ($p = 0.02$). Pregnant women with PR/kg intake lower than the Institute of Medicine recommendations [2] showed a diet with higher milk density ($p < 0.01$). There was no difference in qualitative intake of beans.

The analyses of repeated measurements over time in model A showed systematic intra and inter-individual weight variation (Table 2). Based on the calculation of the intra-class correlation coefficient ($\hat{y} = \sigma_0^2 / \sigma_0^2 + \sigma_\varepsilon^2$), 90% of weight variation was due to differences between women. Inclusion of time as a predictive variable in model B showed that weight variation was linear

with time. Using calculation of statistical *pseudo* R_ε^2 {Pseudo $R_\varepsilon^2 = [(\sigma_\varepsilon^2\ model\ A - \sigma_\varepsilon^2\ model\ B)/\sigma_\varepsilon^2\ model\ A]$}, we estimated that time accounted for 5.4% ($p < 0.0001$) of weight variation over the course of follow-up. The total proportion of level 2 residual variation explained by the predictive variables was 77.8% and was calculated by the equation *pseudo* $R_\zeta^2 = (\sigma_\zeta^2\ model\ B - \sigma_\zeta^2\ model\ F)/\sigma_\zeta^2\ model\ B)$.

Thus, we observed that the inclusion of second order variables explained most of the weight variation. Model C shows that the women lost a mean of 0.079 (±0.03) kg/month ($p = 0.02$). This model included the predictive variable PR/kg and its interaction with time (Table 2). Based on model D, women with adequate protein intake during pregnancy lost 0.111 (±0.04) kg/month more ($p = 0.01$) than women with inadequate intake. Model F showed a monthly weight loss of 0.409 (±0.12) kg among postpartum women with inadequate protein intake in pregnancy ($p < 0.01$) and that women with adequate intake in pregnancy lost 0.094 (±0.04) kg more in the postpartum ($p = 0.03$) as compared to women with inadequate intake. This conditional model was adjusted for the variables energy, percentage body fat, and stature at baseline, and for age, schooling, skin color, and smoking and their interactions with time, except for the interaction variable skin color*time (Table 2).

Figure 2

Hierarchical theoretical model for postpartum weight variation.
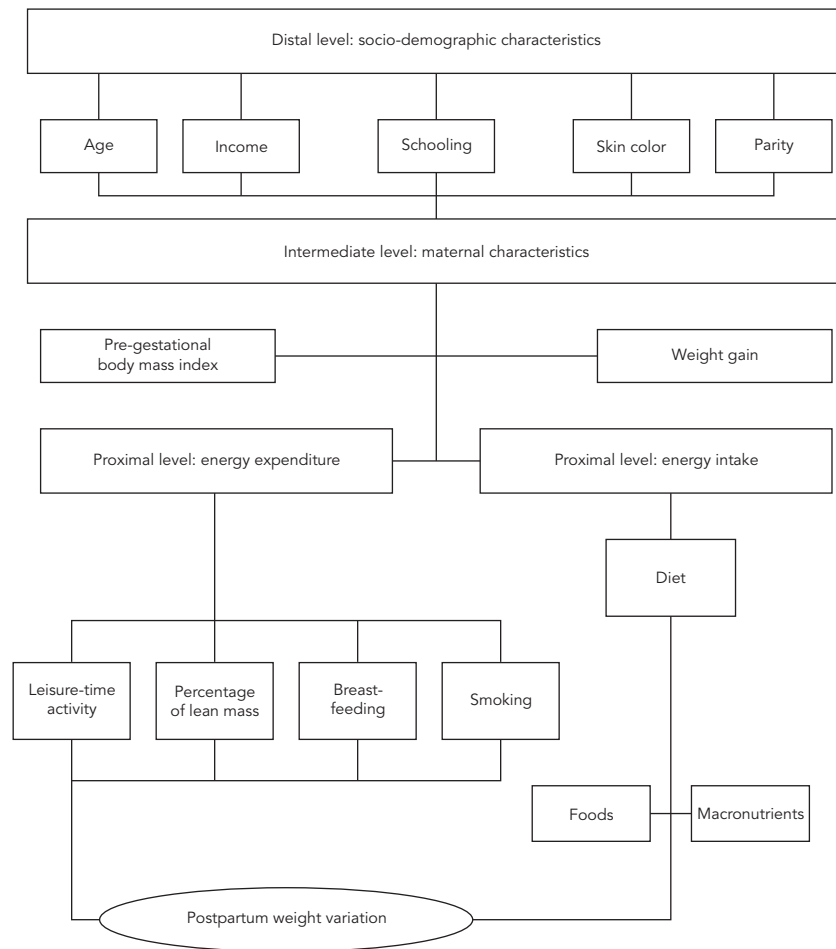
Discussion

In the current analysis, there was a positive association between postpartum weight loss and protein intake per kg of body weight during pregnancy. Women that showed PR/kg intake greater than or equal to the Institute of Medicine recommendations [2] for pregnancy lost more weight in the postpartum than women with inadequate protein intake. Although the difference was not large, namely around 100g/month, this loss can become important over time, both for maintaining and losing weight. Thus, the adoption of a high-protein diet can become a nutritional strategy for postpartum weight loss. Since protein intake is a matter of ordinary food consumption, such a diet is easy to follow and can produce relevant weight reduction over time.

The benefits of a high-protein diet for promoting weight loss have been well documented in the literature [3,4,26,27,28]. However, due to the lack of security in maintaining this type of diet in the long term and its association with the so-called "Western" eating pattern [29,30], pregnant and lactating women are normally excluded from the clinical trials [3,4]. Analysis of usual PR/kg intake was possible due to the reasonable protein intake gradient, although observational studies always have the possibility of residual confounding, even if the analyses are adjusted for known confounding factors.

Table 2

Estimated postpartum weight loss in women with adequate * versus inadequate protein intake ** per kg body weight (PR/kg) during pregnancy.

Parameter	Protein intake during pregnancy		
	Model A	Model B	Model C ***
Fixed effects			
Intercept			
Weight	62.2 ## (±0.59)	62.8 ## (±0.59)	67.8 ## (±0.91)
Adequate intake/Inadequate intake	-	-	-8.4 ## (±1.16)
Variation rate			
Weight*time	-	-0.153 ## (±0.02)	-0.079 ### (±0.03)
Adequate intake*time	-	-	-0.116 ## (±0.04)
Components of variation			
Level 1			
Intra-individual (σ_ε^2)	5.91 ## (±0.27)	5.59 ## (±0.23)	5.58 ## (±0.25)
Level 2			
Inter-individual (σ_0^2)	147.5 ## (±10.21)	147.8 ## (±10.22)	128.7 ## (±9.03)
Goodness-of-fit			
-2 Res Log Likelihood	8,337.8	8,289.8	8,099.1
Akayke Information Criterion	8,341.8	8,293.8	8,103.1
	Model D #	**Model E #**	**Model F #**
Fixed effects			
Intercept			
Weight	64.5 ## (±0.60)	64.8 ## (±1.85)	64.7 ## (±1.85)
Adequate intake/Inadequate intake	-2.90 ## (±0.84)	-2.83 ## (±0.86)	-2.84 ## (±0.86)
Variation rate			
Weight*time	-0.080 ### (±0.03)	-0.451 ## (±0.12)	-0.409 ## (±0.12)
Adequate intake*time	-0.111 ## (±0.04)	-0.099 ### (±0.04)	-0.094 ### (±0.04)
Components of variation			
Level 1			
Intra-individual (σ_ε^2)	5.57 (±0.25)	5.45 (±0.25)	5.46 (±0.25)
Level 2			
Inter-individual (σ_0^2)	35.9 (±2.62)	32.8 (±2.55)	32.8 (±2.55)
Goodness-of-fit			
-2 Res Log Likelihood	7,598.8	7,257.1	7,252.7
Akayke Information Criterion	7,602.8	7,261.1	7,256.7

* Adequate protein intake: PR/kg ≥ 1.2g/kg;

** Inadequate protein intake: PR/kg < 1.2g/kg;

*** Unadjusted model;

Adjusted model;

$p \leq 0.01$;

$p \leq 0.05$.

Note: Models A, B, C, D, E, and F contain random intercepts. Models A and B are referred to respectively as unconditional means model and unconditional growth model. Model C included the predictive variable PR/kg. Model D was adjusted for the variables energy, % body fat, and stature at baseline. Model E included the variables age, skin color, smoking, and schooling and interactions with time. Model F excluded the interaction variable skin color*time. The continuous variables in Models D, E, and F were centered to the mean (population mean value minus the individual value for the variable). We chose the unstructured method that considers the inter-measurement correlation between occasions.

Importantly, the FFQ uses a predefined list of foods, and it is thus impossible to rule out the presence of other protein food sources in pregnant women's diet. The cutoff point of 1.2g protein per kg body weight to classify pregnant women's intake as adequate or inadequate aimed to distinguish women according to dietary protein levels.

Few studies have verified the validity of using FFQ to assess food intake during pregnancy [31,32,33,34]. In Brazil, only one study was found on validation of the FFQ in pregnant women [11]. The

authors discuss the fact that although the FFQ overestimated energy and nutrient intake, the same did not occur with protein intake among pregnant women in the city of Bento Gonçalves, Rio Grande do Sul State, Brazil. Studies outside of Brazil have also concluded that the FFQ is a valid, adequately reproducible instrument for assessing intake in pregnant women, for example Fawzi et al. [32] in the United States and Erkkola et al. [31] and Brantsaeter et al. [34], respectively, on Finnish and Norwegian pregnant women.

One of the difficulties in conducting validation studies in pregnant women consists of the possible variability in intake at different moments in pregnancy and the changes associated with food intolerance or compulsions [13]. In Brazil, Souza & Sichieri [35] and Barros et al. [36] used simplified versions of the FFQ [20] used in the current study to measure food intake in pregnant women and obtained associations that were similar to those reported elsewhere in the literature.

Brown et al. [37], in a study of 56 American women enrolled in the Diana Project on variation in food intake from the pre-gestational period through pregnancy, detected changes in the intake of energy and certain nutrients, as observed in a preliminary analysis of the data under discussion [18]. The authors noted a quantitative decrease in food intake and a qualitative variation in diet from pregnancy to postpartum. The women that most limited their intake from one period to the other showed an increase in dietary protein density.

As expected, women reported higher food intake in pregnancy as compared to postpartum [18], but overestimation of intake cannot be ruled out, especially for commonly recommended foods like fruit, meat, milk, and dairy products. Verbeke & Bourdeaudhuij [12] observed that pregnant women tend to overestimate their consumption of fruit, red meat, milk, and dairy desserts when compared to non-pregnant women.

Other studies have observed the positive effects of high-protein diet on body composition. In a clinical trial by Westerterp-Plantenga et al. [38] on excess weight (n = 148), diets with 20% protein provided greater satiety, and the weight regain rate was 50% lower in the group that received additional protein. Treyzon et al. [39] observed that individuals assigned to the high-protein diet group lost more body fat than those in the control group.

A negative correlation was observed between weight retention and high-protein diet, since women that reported high protein intake were leaner at baseline and at nine months of follow-up. Although it was not possible to assess the exact mechanisms involved in postpartum weight variation, the results suggest the need to monitor protein intake during pregnancy as an additional factor to be considered in the evaluation of nutritional status during this period. The current study corroborated the hypothesis that recommended protein intake in pregnancy favors postpartum weight reduction.

Resumo

Investigar o efeito do consumo de proteína durante a gestação na variação de peso no pós-parto. Trata-se de coorte prospectiva com 421 mulheres entrevistadas aos 15 dias (linha de base), 2, 6 e 9 meses pós-parto. Os dados dietéticos foram obtidos pelo emprego do questionário de freqüência de consumo alimentar com referência para o segundo e terceiro trimestres gestacionais. O consumo protéico foi considerado adequado entre as mulheres com ingestão ≥ 1,2g/kg, e inadequado < 1,2g/kg. Empregou-se o modelo de efeitos mistos para medidas repetidas no tempo. Os resultados mostraram uma perda de peso média de 0,409kg/mês (±0,12) no pós-parto (p < 0,01). Mulheres com consumo adequado de proteína na gestação perderam adicionalmente 0,094kg/mês (±0,04) no pós-parto (p = 0,03) do que as mulheres com consumo inadequado. O modelo foi ajustado para energia, percentual de gordura corporal, estatura, idade, escolaridade, cor da pele e tabagismo. O consumo recomendado de proteína na gestação favoreceu a redução de peso no pós-parto.

Proteína; Período Pós-Parto; Peso Corporal

Contributors

M. B. T. Castro and R. Sichieri participated in the study conceptualization, data analysis and interpretation, and preparation and revision of all versions of the manuscript. G. Kac participated in all stages of the research, from planning to the final revision of the article.

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