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The Direct and Indirect Effects of Macronutrients on Energy Intake in Lactating Mothers

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Abstract

Background: Mother's nutrition during lactation is a factor affecting the quality and quantity of their milk. The present study aimed to investigate the direct and indirect effects of macronutrients on the amount of their energy intake.

Method: This cross-sectional study was conducted in Khorramabad, and the target population included lactating mothers with a lactation period of 12 months or less. Using the dietary record (DR) in three days, the participants' nutritional status and food intake were assessed. For distinguishing the importance of variables based on their direct and indirect effects on energy, non-parametric path analysis was employed.

Results: The median level of energy intake was 1719.60 calories. Carbohydrates and proteins had the strongest and weakest effects on energy intake, respectively; and the strongest indirect effect was observed in fiber, MUFA, and Isoleucine.

Conclusion: Considering the path coefficients related to direct and indirect effects and the effect of each macronutrient on the amount of energy intake, lactating mothers should be informed with the help of intervention programs about the importance of having proper nutrition to receive adequate nutrients and energy.

Key Words: Lactating mother, Lactation, Non-parametric path analysis, Nutritional status.

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1- INTRODUCTION

Lactating mothers' nutrition style might have a significant effect on maintaining the health of babies, and the nutritional value of breast milk can be affected by the amount of nutrients consumed by the mother (1). Inadequate nutritional intake of infants at birth or early development can affect the risk of coronary heart disease and related disorders (2). It is well-known that breast milk is an ideal food source for the proper development of a baby (3). Lactation is very influential in public health through decreasing maternal complications along with the mortality and complications of infancy and childhood; and so it helps control health care costs (4). Lactation is one of the most important stages of the mother's life and is accompanied by an increase in their nutritional needs. It causes the mother, in comparison to a normal person, to require more calories to meet the needs of her infant (5). To be able to produce 500 to 700 ml of valuable milk per day containing the nutrients needed for the growth of the child, in case the needed calories are not received, lactation is done by consuming the reserves of the tissues of the mother's body (6). Reducing calorie intake more than the recommended amount is considered a deficiency, the severity of which affects the incidence of complications in both the mother and the infant. Calorie deficiency causes maternal hunger and ketosis; in this condition, the infant refuses to breast milk and gradually loses weight (7). A mother's malnutrition affects the quality and quantity of her milk. The infant needs enough energy to synthesize her/his tissues and grow. Lack of energy causes the mother's body to deplete its reserves and is associated with the breakdown of adipose tissues. It also makes the mother lose weight, feel weakness, fatigue, and impatience. Eventually, the mother's health is compromised and complications such as osteoporosis, tooth decay, and anemia occur in the mother (8).

The public welfare of a society can be indicated by the nutritional status of women and children. In addition, the food security, public health, and social conditions of the family are reflected by it (9). Few studies have been conducted on the diet of lactating women in Iran (10-15). Calorie deficiency in lactating mothers has been reported by some researchers in Iran (12-14). Among the few studies carried out on the energy intake of lactating mothers in Iran, some have reported the adequacy of energy intake (12, 13), but in some others, the average energy intake has been mentioned to be 1750 kcal, which is lower than the recommended level (10, 14). Studies that have been done so far on the nutrition of lactating mothers and their energy levels have used the method of univariate analysis and examined the relationship between energy with demographic variables or individual nutrition or anthropometric indicators (10-12). And, none of these studies have investigated the direct and indirect effect of macronutrients on the amount of energy intake.

When the purpose is to investigate the direct and indirect effects of independent variables on the dependent variable, one of the rigorous statistical methods is path analysis, which shows how much each variable, directly and indirectly, affects the response variable. In path analysis, the type of relationship between the independent variables and the response variable must be clear. When complete information about the nature and form of this relationship is not available, using a hypothetical model can lead to erroneous conclusions. In these cases, instead of assuming a specific relationship in the model and non-parametric methods, the desired correlations are estimated (16). The aim of this study is to detect the direct and indirect effects of macronutrients on

the amount of energy intake in lactating mothers. By finding the effect of each of these items on the amount of energy, along with having a healthy diet, the amount of energy required by the body can be also provided.

2- MATERIALS AND METHODS

This cross-sectional study was conducted in Khorramabad, the capital of Lorestan Province, Iran. The target population of the study included the lactating mothers who were referred to health centers in Khorramabad from April to June 2012. A multi-stage clustering sampling method was utilized to select the sample. First, the city of Khorramabad was divided into two regions (urban and rural); then in each region, health centers were considered as clusters, and finally, according to the number of available documents, the individuals were selected systematically. The inclusion criteria of this study encompassed the lactating mothers over the age of 18, lactation period of 12 months or less, and willingness to participate in the study. Individuals with chronic diseases or lactation for less than three months were excluded from the study. The required sample size was estimated to be 720 participants based on the PASS software using a confidence level of 95%, with the ratio of mothers receiving sufficient energy being 50.3% (12), a margin of error of 4%, and 20% drop. A total of 720 lactating mothers were assessed for eligibility, out of which 708 individuals met the inclusion criteria. All participants received information about the study and provided their written informed consent.

Using the dietary record (DR) in three days (two days a week and one weekend), the participants' nutritional status and food intake were assessed. To complete the questionnaires, 16 nutritionists assisted the researcher, and the participants were asked to memorize and report all foods, supplements, and beverages they had consumed excessively. A manual was used to convert the amount of food consumed to the daily amount in grams. Nutritionist IV software (N-Squared Computing, SanBruno, CA, USA) was applied to calculate energy, macronutrients, and micronutrients. Computer codes for combining Iranian food have been added to this software by Azar and Sarkisian (17). The adequacy of the received energy was obtained by dividing the received amount of energy consumption by the recommended amounts.

2-1. Statistical methods

Although regression analysis is used in various studies, it is not able to show complex relationships when there are several Mediator variables. Therefore, path analysis is designed to form a model with the relationship between the variables described by directions. Finally, the model is built in path analysis based on the path diagram (18).

In parametric methods, a special feasible link function, which links the response variable to independent variables, is imposed on the data, but when the type of relation between independent and dependent variables is unknown based on the data, the rational link function is considered. Nonparametric regression can estimate the regression curve without requiring strong preconditions about the functional form of the regression curve. These techniques are useful both for describing the data and for constructing and examining the model. In other words, the goal is to find the shape of the smoothed curve fitted to the data. The parametric path analysis method needs a suitable sample size and normal data distribution. According to Ringle, non-parametric path analysis methods, compared to the parametric ones, require smaller sample size and do not require the normality assumptions (19). **Fig. 1** was considered as a hypothesized path model, based on previous research evidence (20-

26). In this diagram, the direct and indirect effects of the variables on energy are assumed. For protein, carbohydrates, and fats only direct effects are drawn. For other variables, in addition to the direct effect, their indirect effects are also considered. All the statistical analysis was done by R software version 4.0.4. This study was approved by the Research Ethics Committee of Tarbiat Modares University, Tehran, Iran (IR.MODARES.REC.1399.155).

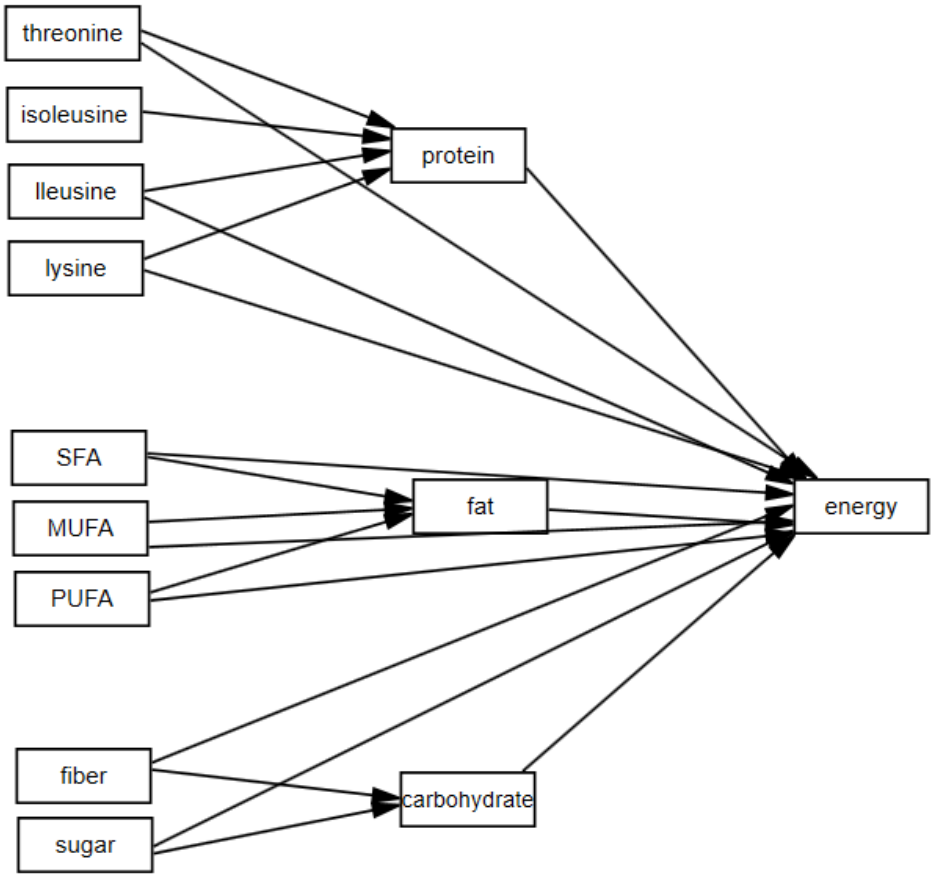

Fig. 1: The hypothesized path diagram for the relationships between energy and macronutrients

3- RESULTS

The mean age of the mothers was 29.78 ± 6.24 years old. Among the participants, 303(42.8%) were urban and 405 (57.2%) were rural. The mean BMI was 26.11±3.69 and 196 patients (27.70%) had a normal BMI (18.5 to 24.9 kg/m^2), 22.9% (n=162) were thin (<18.59 kg/m^2), prevalence overweight and obesity (>259 kg/m^2) was 49.4 percent. Illiteracy rate was 11.72% (n=83) and 13.86% (n=96) had academic education. The majority of mothers (75.3%, n=533) had less than 3 children and most of them (93.2%, n=660) were housewives. Precisely, 658(92.9%) mothers said that their infants' breastfeeding was in good condition. There were 229 (42.2%) mothers whose child was up to 6 months old. The result revealed that 76 (10.8%) mothers started complementary feeding for their children between 4 and 6 months; and 632 (89.2%) from the age of 6 months. The mean, median, and the first and third quartile of energy and macronutrients are shown in **Table 1**.

Table-1: The intakes of energy and macronutrients by the lactating mothers

Variable	Minimum	Maximum	Median ($P25^{*}; P75^{**}$)	mean±SD
Energy (kcal)	954.59	4712.28	1719.60 (1399.74; 1999.01)	1778.47±559.28
Protein (g)	38.93	161.91	69.88 (56.76; 92.47)	76.29±28.67
Carbohydrate (g)	105.58	479.84	214.52 (170.52; 255.91)	222.31±69.93
Fat (g)	26.24	240.38	63.70 (48.55; 75.67)	68.14±28.57
SFA (g)	5.93	56.06	15.77 (14.37; 23.07)	18.59±7.71
MUFA (g)	7.65	86.61	20.50 (14.69; 24.27)	23.50±12.58
PUFA (g)	9.87	65.51	18.53 (13.84;24.35)	19.72±7.86
Fiber (g)	1.77	31.06	10.13 (7.31; 13.43)	11.18±5.16
Sugar (g)	11.29	103.53	29.86 (18.33; 40.04)	35.90±20.46
Threonine (mg)	1369.43	5675.23	2180.09 (1625.68; 3281.90)	2438.40±979.31
Isoleucine (mg)	1541.83	6754.91	2588.88 (1923.52; 3750.60)	2893.86±1175.43
Leucine (mg)	2693.49	11060.39	4459.39 (3332.68; 6298.96)	4965.42±1974.43
Lysine (mg)	1742.34	10670.76	3291.10 (2659.90, 5447.09)	4008.31±1763.77

* The 25th percentile ** The 75th percentile

Fig. 2 shows the path diagram with standardized direct path coefficients. The results of non-parametric path analysis are presented in **Table 2**. According to **Table 2**, leucine had a significant positive effect (1.791), and lysine had a significant negative effect (-0.492) on the protein (P <0.001), isoleucine (P=0.605), and threonine (P=0.573) having no significant effect on the protein. Regarding the effects of saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), and polyunsaturated fatty acid (PUFA) on fat, it was revealed that all three variables had significant positive effects (P <0.001), and PUFA with a standardized path coefficient of 0.498 had the greatest effect; SFA and PUFA had approximately the same effects. As for the effects of fiber and sugar on carbohydrate intake, both variables had significant effects (p <0.001), and fiber with a coefficient of 0.582 was found to have a greater effect than sugar with a standardized coefficient of 0.417 on carbohydrates. Finally, in the non-parametric path analysis, the effects of fat, protein, carbohydrate, and all the previously studied factors on these three variables were examined. Carbohydrate, fat, and protein had the strongest effects on the amount of energy intake, respectively (p <0.001). The standardized direct,

indirect, and total effects of mono-unsaturation, obtained by non-parametric path analysis, are presented in **Table 3**. The results revealed that fiber, MUFA, and isoleucine had the greatest total effect on energy intake; on the other hand, leucine had the weakest effect. It was also observed that lysine inversely affected the amount of energy intake.

4- DISCUSSION

This study aimed to investigate the direct and indirect effects of macronutrients on the energy intake of lactating mothers in Khorramabad. Similar to other studies conducted in Iran, a large number of the lactating women were in the age range of 25-35 years (12, 14). According to the results, most mothers started their children's complementary foods at six months. In a study conducted in Iran, starting complementary foods for about 76% of babies began when they were about 6 months old; a study conducted in Qazvin had reported 7.5±1.1 months as the starting point for consuming the complementary foods (27, 28). The median energy intake in the present study was less than DRI (2380 kcal), showing that half of the mothers received less than the required amount of energy. This result is similar to the findings of Abedini's study in Qom (12). In separate studies in China and Zambia, the median energy intake was 1640.95 kcal and 1697 kcal, respectively (20, 21). In the present study, the median protein intake was 69.88 g/d, indicating that the received protein in about half of the individuals was less than the amount required by DRI (71 g/d). The results of this study are in line with Zhenjie Wang's study conducted in Tibet (23). In a study conducted in Brazil, the mean maternal protein level was calculated in regard to the infant's age, with the lowest amount (88) being higher than the expected level (29).

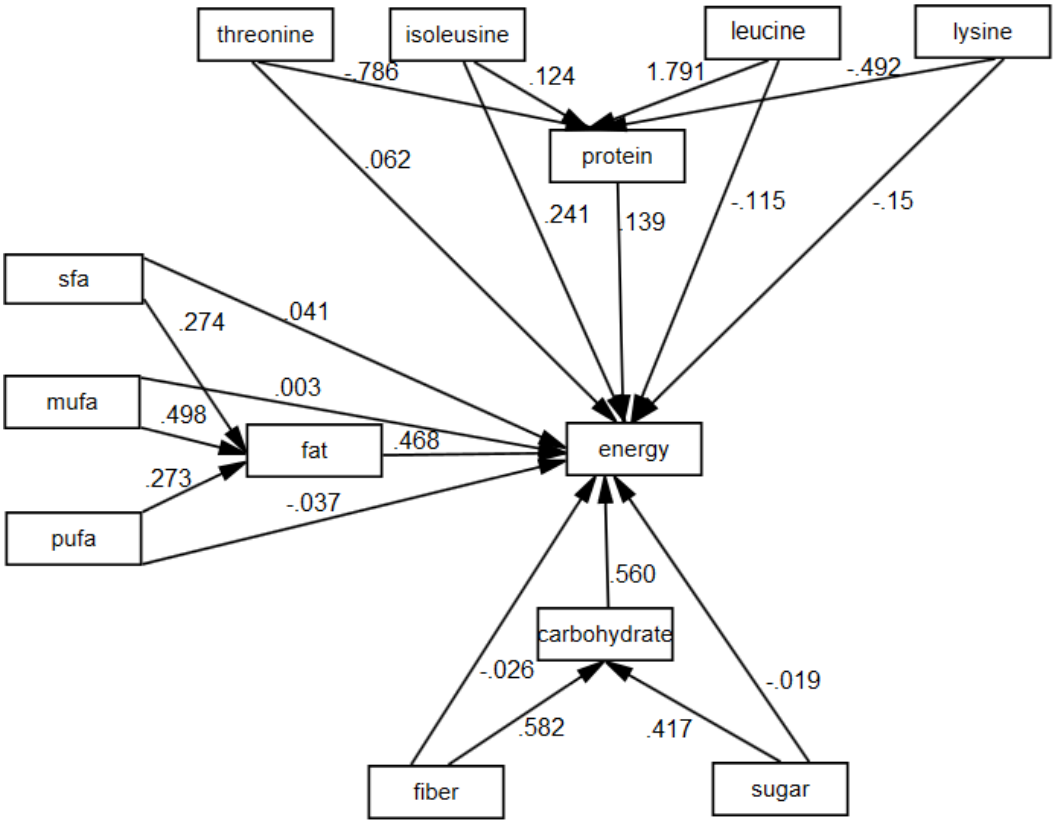

Fig. 2: The final path diagram for the relationships between energy and macronutrients

Table-2: The standardized path coefficients based on nonparametric path analysis

Model		Coefficient estimate	Bootstrap Std. Err	p-value
Protein	Threonine	-0.786	0.004	0.605
	Isoleucine	0.124	0.003	0.573
	Leucine	1.791	0.001	<0.001
	Lysine	-0.492	0.002	<0.001
Fat	SFA	0.274	0.018	<0.001
	MUFA	0.498	0.019	<0.001
	PUFA	0.273	0.023	<0.001
Carbohydrate	Fiber	0.582	0.49	<0.001
	Sugar	0.417	0.18	<0.001
Energy	SFA	0.041	0.440	<0.001
	MUFA	0.003	0.265	0.618
	PUFA	-0.037	0.263	<0.001
	Fiber	-0.026	0.488	<0.001
	Sugar	-0.019	0.093	<0.001
	Threonine	0.062	0.286	0.224
	Isoleucine	0.241	0.013	<0.001
	Leucine	-0.115	0.010	<0.001
	Lysine	-0.15	0.009	<0.001
	Protein	0.139	0.13	<0.001
	Fat	0.468	0.09	<0.001
	Carbohydrate	0.560	0.06	<0.001

Table-3: The standardized direct, indirect, and total effects of invested variables on energy, obtained from path analysis

Macronutrients	Direct effect	Indirect effect	Total effect
Protein	0.139	No	0.139
Carbohydrate	0.560	No	0.560
Fat	0.468	No	0.468
SFA	0.041	0.1460	0.1870
MUFA	0.003	0.2660	0.2690
PUFA	-0.037	0.1460	0.1090
Fiber	-0.026	0.3260	0.3000
Sugar	-0.019	0.2330	0.2140
Threonine	0.0620	-0.023	0.0390
Isoleucine	0.24100	0.0170	0.2580
Leucine	-0.115	0.186	0.0710
Lysine	-0.15	-0.067	-0.217

The median carbohydrate was 214.52 g/d, which is higher than the DRI (210 g/d), meaning that at least half of the cases received enough carbohydrates. This amount was equal to 234 in the study conducted in Shanghai (30) with a similar result to the present study, but in studies conducted in China and Beijing, this amount was lower than the expected (20, 31). The median fat intake among the women in our study was 63.70 g/d, which was higher in some other studies (20).

However, in some other studies, such as those carried out in Umuahia and Tibet, fewer amounts have been observed (23, 32).

The results of the present study showed that lysine had a negative effect, isoleucine and threonine had no significant effect, and leucine had a positive effect on the amount of protein intake. According to standardized path coefficients, regardless of their sign, the intensity of Leucine's effect on the protein was twice more than that of threonine. Examination of the effects of SFA, MUFA, and SUFA on fat showed that the intensity of the MUFA effect was about twice more than the effects of the two other factors. The median values of these variables were 15.77, 20.50, and 18.53, respectively, compared to a study in China with 16.88, 31.37, and 13.53 values (20). In this study, Fiber intake for at least 75% of study participants was below the standard level (30 g), which was consistent with the results of some studies conducted in China and Italy (33, 34). The effects of fiber and sugar on carbohydrates were also investigated, showing that although both have a positive effect, the effect of fiber is 1.4 times stronger than sugar.

Among the variables that directly affected the amount of energy intake, the intensity of the effect of carbohydrates was the strongest variable followed by fat intake. As far as we know, in the studies that have been done so far, statistical modeling has not been conducted in investigating the effect of macronutrients on energy intake, and only the share of each of them in energy production is expressed as a percentage. In Haijiao Chen's study in China, carbohydrates (39%-44%) and fats (34%-42%) had the highest share in energy intake, and protein had the lowest share (20%-23%) (34). Similar results have been reported in studies in Brazil, China, and Hong Kong (20, 29, 35).

In this study, the direct and total effect of each variable on the received energy was considered. By examining the direct effects, it is observed that among the first level variables, PUFA, fiber, sugar, leucine, and lysine had a negative effect on the received energy, but with a consideration of the effects of the mediating variables, the total effect of all these variables has become positive. For this reason, to interpret the effect of macronutrients, we consider the total effect of each variable.

The standardized total effects showed that fiber played the most important role in the energy received. Another variable that can increase energy is sugar. A study by Raben on normal-weight women also found that increasing sugar consumption increases energy (36). Among the fat components, MUFA has the strongest effect on energy. This finding is in line with those of the studies in China and Hong Kong showing that MUFA had a higher percentage of energy supply (20, 35).

Among the studied amino acids, the most effect is related to isoleucine. To the best of our knowledge, the relationship between energy and isoleucine has not been studied. A study investigating the relationship between leucine and body mass index in the elderly has reported a positive relationship between the two variables (24). In the present study, lysine had a negative effect on energy intake. A study on rats showed a negative relationship between lysine and energy (26), while another investigation on healthy men and women revealed no significant relationship between the two variables (25).

Based on the results, informing lactating mothers about the factors that have a greater share in producing the energy is recommended; so that they can have appropriate diets for maintaining optimal lactation without depleting mother's nutrient reserves. Significant total effects

of fiber and MUFA are confirmed for the lactating mothers; and can be increased through the intake of fruits, fresh vegetables, and fish. All of them, especially those who do not receive enough nutrients, should be recommended to use multivitamins and supplements. Using nutritional counseling is thus vital for all women, especially the lactating mothers, in order to keep themselves and their babies healthy.

5- CONCLUSION

Due to the lack of simultaneous consideration of some important variables, a univariate analysis may lead to misleading results so using more sophisticated statistical methods is unavoidable. In the present study, the use of path analysis instead of univariate methods showed the relationships more realistically. The nutrition status of lactating mothers in urban and rural areas in Khorramabad is characterized by insufficient food and nutrient intake, which does not meet the DRIs. Based on our findings, broader investigations on fiber, MUFA, and sugar assessments in the future are suggested to understand changes in the diet structure of the populations; since, the growth and development of the baby depends on the health and nutritional status of the mother.

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7- CONFLICT OF INTEREST STATEMENT

None.

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