

Renal Functional Reserve in Lacto-vegetarian Adolescents

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Abstract : A high-protein meal causes an increase in the glomerular filtration rate (GFR) and is a tool to assess renal functional reserve. This study aimed to assess the GFR and renal functional reserve in lacto-vegetarians who had abstained from protein from animal sources for years. Twenty healthy lacto-vegetarian adolescents (LVA) aged 12-15 years including ten males and ten females were recruited. They had consumed no meat, poultry, fish or eggs for 1.0 - 4.8 years (average 2.13 ± 1.03 years). An age-and-sex matched control group composed of adolescents who regularly consumed a mixed diet from both animal and vegetable sources (MDA). The baseline GFR was assessed in each subject using the 24-hour creatinine clearance method. Then each subject consumed a meal containing 1.2 grams of protein per kg body weight in the form of steamed chicken breast. After this meal, urine and blood specimens were collected for GFR assessment every 30 minutes for three-and-a-half hours. The result showed that the LVA had a lower baseline GFR compared to the MDA (72.6 ± 7.7 vs 89.3 ± 14.9 ml/min/1.73 m²). A high-protein meal caused an increase in GFR of 60.3 per cent in the LVA and 76.2 per cent in the MDA. The LVA group whose protein intake was rather low and who had abstained from animal protein for several years showed a smaller and slower response to the renal-hyperfiltration effect of a high animal-protein diet. This might be due to changes in gastro-intestinal digestion and absorption of protein, or changes in renal hemodynamics, other renal functions or structures. In addition, the study revealed that the LVA group had lower body weight, height, body surface area, hemoglobin, serum cholesterol and uric acid concentrations. The female LVA reached menarche at a later age compared to the MDA group. In conclusion, lacto-vegetarian adolescents showed a lower baseline GFR and less renal functional reserve compared to those regularly consuming protein from animal sources.

Key words : Renal functional reserve, GFR, Glomerular filtration, Vegetarian.

เรื่องย่อ : กำลังสำรองของไตในวัยรุ่นมังสะวิรัติ

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อาหารโปรตีนสูงมีผลทำให้ไตทำงานมากขึ้นและอัตราการกรองของไต (glomerular filtration rate, GFR) เพิ่มขึ้น นิยมใช้การให้อาหารโปรตีนสูงหนึ่งมื้อ เป็นวิธีหาค่าสำรองของไต (renal functional reserve) การวิจัยนี้ศึกษาว่าเด็กวัยรุ่นที่บริโภคอาหารมังสะวิรัติแบบดื่มนมด้วย (lacto-vegetarian) ได้โปรตีนน้อย ไตไม่ถูกกระตุ้นโดยโปรตีนจากสัตว์มาแรมปี การตอบสนองของไตต่อการกระตุ้นด้วยโปรตีนจากสัตว์จะคงเหมือนคนวัยเดียวกันที่บริโภคอาหารโปรตีนจากสัตว์เป็นประจำหรือไม่ ทำการศึกษาในวัยรุ่นผู้มีสุขภาพดี อายุ 12-15 ปี แบ่งเป็น 2 กลุ่ม คือ กลุ่มมังสะวิรัติ และกลุ่มไม่ดื่มนมสัตว์ แต่ละกลุ่มมีจำนวน 20 คน เป็นชาย 10 คนและหญิง 10 คน ทุกคนเก็บปัสสาวะ 24 ชั่วโมง และเจาะเลือด เพื่อนำมาหาค่าอัตราการกรองของไตโดยคำนวณจากอัตราการขับครีเอตินิน แล้วจึงวัดค่าสำรองของไต โดยให้รับประทานอาหารโปรตีน 1.2 กรัมต่อน้ำหนักตัว 1 กิโลกรัม ในรูปอกไก่อบ ภายหลังรับประทาน เก็บปัสสาวะและเจาะเลือดเพื่อหาค่าอัตราการกรองของไตทุก 30 นาทีเป็นเวลา 3 ชั่วโมง 30 นาทีเปรียบเทียบ พบว่ากลุ่มมังสะวิรัติซึ่งละเว้นเนื้อสัตว์มานาน 1.0-4.75 ปี (เฉลี่ย 2.13 ± 1.03 ปี) มีอัตราการกรองของไตใน 24 ชั่วโมง เท่ากับ 72.60 ± 7.74 มล./นาที/1.73 ตร.ม. ต่ำกว่ากลุ่มที่ไม่งดเนื้อสัตว์ซึ่งมีอัตราการกรองของไตเท่ากับ 89.27 ± 14.89 มล./นาที/1.73 ตร.ม. และเมื่อรับประทานโปรตีนจากเนื้อสัตว์ กลุ่มที่ได้โปรตีนจากสัตว์เป็นประจำจะมีอัตราการกรองของไตเพิ่มสูงขึ้นร้อยละ 76.24 ส่วนกลุ่มมังสะวิรัติมีอัตราการกรองของไตเพิ่มขึ้นช้ากว่าและเพิ่มได้น้อยกว่า คือสูงขึ้นเพียงร้อยละ 60.30 แสดงว่าการรับประทานอาหารมังสะวิรัติมานานหลายปีมีผลลดการตอบสนองของไตซึ่งอาจเป็นเพราะมีการเปลี่ยนแปลงในการย่อยและดูดซึมในทางเดินอาหาร หรือมีการเปลี่ยนแปลงในโครงสร้างของไต นอกจากนี้ยังพบว่า กลุ่มมังสะวิรัติมีน้ำหนัก ส่วนสูง พื้นที่ผิวกาย ระดับฮีโมโกลบิน โคเลสเตอรอล และกรดยูริกในเลือดน้อยกว่ากลุ่มที่ไม่งดเนื้อสัตว์ และมีประจำเดือนครั้งแรกมาช้ากว่าด้วย โดยสรุป เมื่อทดลองให้กลุ่มมังสะวิรัติรับประทานอาหารที่มีโปรตีนจากสัตว์ในปริมาณสูง พบว่ามีการตอบสนองของไตช้ากว่าและน้อยกว่ากลุ่มที่ได้รับเนื้อสัตว์เป็นประจำ

INTRODUCTION

The new wave of interest in health and physical fitness has encouraged increasing number of individuals to reject meat and turn to eating more vegetables and fruits. A vegetarian diet has become increasingly popular for health, ecological, philosophical and religious reasons. Vegetarian diets are classified into 5 types : semi-vegetarian, lacto-ovo-vegetarian, lacto-vegetarian, vegan and fruitarian¹. The lacto-vegetarian diet includes grain, pulps, nuts, seeds, fruit and vegetable, and excludes all meat, poultry, game, fish and eggs, while milk and dairy products are consumed. The diet is high in fiber which may be either water-soluble or insoluble. Dietary fiber plays an important role in modifying digestive functions². The diet is also low in protein. Since a high protein diet increases the solute load to the kidneys and causes renal hyperperfusion and

hyperfiltration, many physicians recommend that patients with renal insufficiency and elderly people should watch their protein intake³. The effect of protein on renal function lasts for many hours after a meal⁴, so in the long run it may result in permanent renal functional and structural modification. In Thailand, certain groups of adolescents have been put on vegetarian diet for economic, cultural or religious reasons. The effect of diet on renal function is thus worth investigating in this selected group.

MATERIALS AND METHODS

The study was conducted in two groups of adolescents, the LVA (lacto-vegetarian adolescent) and MDA (mixed-diet adolescent) groups, each composed of ten male and ten female subjects aged 12-15 years. The LVA subjects had taken a strict

vegetarian diet for at least one year before the study (1.0 - 4.75 years or 12-57 months, mean duration 2.13 ± 1.03 years or 25.60 ± 12.31 months). Their food was mostly grains and vegetables. Meat and eggs were excluded but milk and dairy products were included. These healthy subjects were volunteers from Santi Asoke, a private owned religious campus in a suburban area of Bangkok.

The MDA subjects consumed a regular diet of both animal and plant products. They were students from Chinoros Vithayalai School in Bangkoknoi District, Bangkok.

All forty subjects underwent general physical examination. Screening uristix test for urine protein and sugar showed negative results. Written informed consent was obtained from each subject and his or her parents.

Venous blood samples were drawn to determine fasting blood sugar (FBS), cholesterol, triglyceride, total protein, uric acid, blood urea nitrogen (BUN), creatinine, hematocrit and hemoglobin. Urine samples were also collected to measure urine creatinine excretion.

Creatinine clearance (Ccr) was calculated from the standard equation $Ccr = UV/P$, where U = urine creatinine concentration, V = urine flow rate and P = plasma creatinine concentration. The clearance of creatinine represents the glomerular filtration rate (GFR)⁵.

All subjects collected their urine for 24 hours before the high protein test meal so that baseline values of 24-hour creatinine clearance were obtained. Chicken breast was used as the source of protein. Each subject ingested 1.2 g of protein per kg body weight together with cooked rice 1.5 g/kg body weight to render the meal acceptable for lacto-vegetarians. This meal gave 9.85 kcal/kg body weight.

Urine and blood samples were collected every thirty minutes for three-and-a-half hours after the meal for creatinine clearance measurements.

All results are expressed as mean $\pm$ standard deviation. On Kolmogorov-Smirnov tests all data were normally distributed. Unpaired t-tests were used to analyze parameters in the same group of subjects at different periods of time. Paired t-tests were used to compare the same parameter between groups at the same period of time. Pearson correlation was used to analyze the correlation between two groups of parameters. A *p*-value < 0.05 was considered statistically significant.

RESULTS

Demographic data for the two groups of subjects are shown in Table 1. Comparing the LVA and the MDA groups, the vegetarians had a lower body weight, height, BSA and BMI and later menarche.

Table 1. Demographic data (mean $\pm$ SD).

Variables	LVA (n = 20)	MDA (n = 20)	Student t-test
Age (years)	13.75 ± 0.97	13.75 ± 0.97	NS
Height (cm)	150.0 ± 9.3	158.7 ± 7.3	$p < 0.01$
Weight (kg)	41.5 ± 7.4	49.6 ± 10.8	$p < 0.01$
BSA (m ²)	1.31 ± 0.15	1.48 ± 0.17	$p < 0.01$
BMI (kg/m ²)	18.4 ± 1.7	19.6 ± 3.4	NS
Systolic BP (mmHg)	100.7 ± 9.2	105.0 ± 10.0	NS
Diastolic BP (mmHg)	64.4 ± 7.2	64.9 ± 7.4	NS
Menarche (age in years)	13.0 ± 1.1	11.8 ± 1.2	$p < 0.05$

The mean blood chemistry data are shown in Table 2. All values were within normal limits. There was no difference in the fasting blood sugar, triglyceride and total protein concentrations between

the two groups of subjects. Hematocrit, blood cholesterol and uric acid concentrations were significantly lower in the vegetarian group.

Table 2. Blood chemistry data (mean $\pm$ SD).

Variables	LVA (n = 20)	MDA (n = 20)	Student t-test
FBS (mg/dl)	86.8 $\pm$ 8.3	87.9 $\pm$ 6.3	NS
Cholesterol (mg/dl)	141.4 $\pm$ 21.4	172.4 $\pm$ 27.3	$p < 0.001$
Triglyceride (mg/dl)	71.0 $\pm$ 21.6	72.3 $\pm$ 35.1	NS
Uric acid (mg/dl)	4.04 $\pm$ 0.72	5.30 $\pm$ 1.08	$p < 0.001$
Systolic BP (mmHg)	100.7 $\pm$ 9.2	105.0 $\pm$ 10.0	NS
Total protein (gm/dl)	7.61 $\pm$ 0.41	7.66 $\pm$ 0.35	NS
Hemoglobin (gm/dl)	11.42 $\pm$ 1.66	12.65 $\pm$ 0.97	$p < 0.05$

The creatinine clearances representing the GFR before and after the meat meal are shown in Table 3 and Figure 1. The LVA had a lower baseline GFR and their GFR increased to a much lower extent in response to a high protein meal. At three-and-a-

half hours after meal, the GFRs were still a bit higher than the baseline values (before meal) in both groups of subjects. Comparison of renal function in male and female was not assessed in this study.

Table 3. Creatinine clearance (ml/min/1.73m²) before and after the meat meal.

Time after meal	LVA (n = 20)	MDA (n = 20)	Student t-test LVA to MDA group
Baseline (- 30 min)	72.6 $\pm$ 7.7	89.3 $\pm$ 14.9	$p < 0.001$
30 min	114.1 $\pm$ 19.1 **	157.3 $\pm$ 58.7 **	$p < 0.01$
60 min	100.9 $\pm$ 22.5 **	115.1 $\pm$ 40.3 *	NS
90 min	106.0 $\pm$ 16.4 **	116.8 $\pm$ 22.1 **	NS
120 min	116.4 $\pm$ 20.5 **	111.5 $\pm$ 15.4 **	NS
150 min	101.5 $\pm$ 18.2 **	109.1 $\pm$ 16.2 *	NS
180 min	101.9 $\pm$ 10.3 **	103.7 $\pm$ 16.5 *	NS
210 min	95.7 $\pm$ 13.5	102.1 $\pm$ 19.4	NS

* $p < 0.01$ and ** $p < 0.001$ compared to the baseline value in each group.

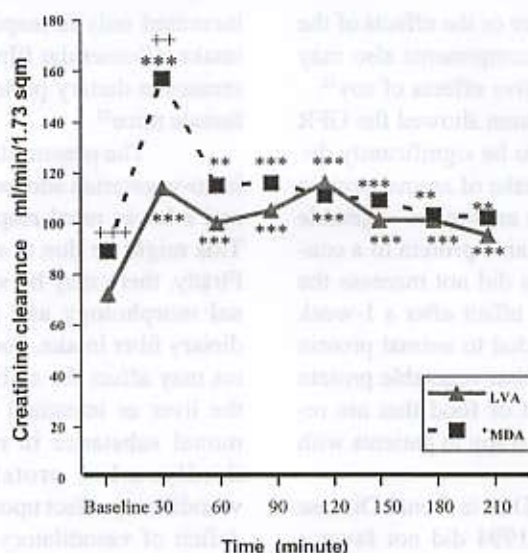


Figure 1. Creatinine clearance before and after the animal protein meal $*p < 0.01$, $**p < 0.001$ compared to baseline value in each group. $+p < 0.01$, $++p < 0.001$ comparing between groups at the same period of time.

DISCUSSION

This presented study found that vegetarian adolescents LVA, who maintained their vegetarian status for more than one year, showed lower baseline GFR values and lower renal response to an acute animal protein load comparing to the omnivorous MDA. The GFR increased to a peak at 30 minutes after meal both in LVA and MDA. Though the peak GFR value in LVA was not as high as the MDA, the hyperfiltration effect persisted up to three-and-a-half hours in both groups. This suggested that, in LVA, a high meat diet could cause renal vasodilation or hyperfiltration similar to the MDA but the maximal response was not as high.

A protein meal, either from plants (like soy bean) or an animal source, can cause an increase in GFR for at least a few hours^{6,7}. Dietary protein and certain amino acids cause glomerular afferent vasodilation resulting in renal hyperperfusion and glomerular hyperfiltration^{8,9}. A chronic high intake of protein can cause permanent structural changes of the renal vasculature.

In a prospective study, the effect of chronic dietary protein intake on renal function in 88 healthy

subjects (vegetarians, body-builders and subjects with no special diet) were examined for at least 4 months. This investigation showed that chronic protein intake of varying amounts was a crucial control variable for the glomerular filtration rate. It is suggested that these changes reflect in part structural changes of the glomerulus and tubules due to chronic protein intake¹⁰.

A vegetarian diet is generally low in protein and vegetable protein may not be fully available as it is not so easily digested and absorbed by the human digestive tract². Furthermore, long term consumption of a vegetarian diet may alter the morphology of the intestinal villi and their function¹¹. The plasma cholesterol was significantly lower in the LVA subjects than in the MDA. A study in obese rats suggested that a soy diet prevented the development of hypercholesterolemia, primarily low-density lipoprotein (LDL) and/or very low-density lipoprotein (VLDL) cholesterol, and slowed the development of proteinuria and glomerular injury. An important determinant of the protective effects of soy was related to the prevention of hypercholesterolemia in this model. Other factors such as differences in glo-

merular capillary blood pressure or the effects of the antioxidant properties of soy components also may have contributed to the protective effects of soy¹².

A study in 7 healthy men showed the GFR and renal plasma flow (RPF) to be significantly decreased after decreasing the intake of animal protein by one third while keeping the amount of vegetable protein constant. Adding vegetable protein to a constant amount of animal protein did not increase the GFR and RPF. The lack of an effect after a 1-week intake of vegetable protein added to animal protein on the GFR and RPF suggests that vegetable protein may be excluded from the list of food that are restricted in a low protein diet therapy in patients with renal insufficiency¹³.

The Modification of Diet in Renal Disease (MDRD) Study published in 1994 did not favor a low protein diet in the management of chronic renal failure. But this is still a controversial issue especially with respect to recommendation of the National Institute of Diabetes, Digestive and Kidney Diseases, National Institutes of Health, USA. The balance of evidence is more consistent with the hypothesis of a beneficial effect of protein restriction than with the contrary hypothesis of no beneficial effect¹⁴.

In mice, an increased protein intake resulted in an increase in the liver, kidney and stomach masses, while digestive tract and other vital organ masses

increased only in response to an increase of energy intake. Glomerular filtration rates increased with increases in dietary protein level in male mice but not female mice¹⁵.

The present study showed that the long-term lacto-vegetarian adolescents had lower baseline GFR and a lower renal response to an oral protein load. This might be due to at least three possible factors. Firstly, there may be some changes in gastrointestinal morphology and function after years of high dietary fiber intake. Secondly, altered nutritional status may affect the ability of a specific tissue such as the liver or intestinal mucosa to synthesize a hormonal substance in response to a stimulus. And thirdly, a low protein diet provides a smaller vasodilatory effect upon renal arteriole and long-term deficit of vasodilatory stimuli may reduce the ability of the arterioles to dilate.

In conclusion, a long-term vegetarian diet certainly causes a change in some body functions compared to a mixed diet. Both the benefits and harms should be kept in mind when adhering to any extreme diet especially for young children, the elderly, cancer patients, or some patients who can easily become malnourished. Long-term follow up of renal function and response as well as other system functions and responses in these vegetarian subjects are important and interesting.

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