Dietary carnitine effects on carnitine concentrations in urine and milk in lactating women[1,2]

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ABSTRACT The effect of dietary carnitine on urinary excretion of free and total carnitine and on breast-milk secretion of the carnitine fractions in 15 control and 16 lactating women aged 21–40 y was measured. Free and total carnitine excretions, obtained from 24-h urine collections, correlated with carnitine consumed on the collection day ($P < 0.03$, $P < 0.01$, respectively) but not with the mean intake calculated from 3-d diet records. The immediate responses of the control and lactating groups were not significantly different. Urinary excretion of carnitine ($n = 31$) was 82 ± 13 μmol/d for free excretion and 226 ± 22 μmol/d for total excretion. Milk free, acid-soluble acyl-, acid-insoluble acyl-, or total carnitine did not correlate with dietary carnitine or with the duration of lactation (1–10 mo). Milk total carnitine was 45 ± 3 μmol/L. With the carnitine content of breast milk remaining stable for ≥ 10 mo, the importance of exogenous carnitine throughout infancy is suggested. *Am J Clin Nutr* 1991;54:814–20.

KEY WORDS Carnitine, acylcarnitine, lactation, urine, breast milk

Introduction

Carnitine functions primarily as a carrier molecule, transporting long-chain fatty acids across the inner mitochondrial membrane, thereby facilitating β-oxidation (1). Other possible functions include its role in branched-chain–amino acid catabolism, the removal of chain-shortened products from the peroxisomes, the modulation of the ratio of acyl-coenzyme A (CoA) to coenzyme A (CoASH) (especially in the mitochondrial matrix) (2), gluconeogenesis (3), and the storage of acetyl groups in spermatogenesis (4).

Carnitine is not considered an essential nutrient for humans because the body can normally synthesize it from lysine and methionine. Dietary sources of carnitine are predominantly red-muscle meat, with the highest concentrations in lamb and beef (5). Because rich dietary sources are so specific, a normal diet can vary considerably in carnitine content. Usual daily carnitine intakes have been reported to range from 10 to 620 μmol (2 to 100 mg), reaching 1850 μmol (300 mg) in some cases (3). Because normal daily urinary excretion of total carnitine is only 100–300 μmol (4), excess dietary carnitine must be destroyed by indigenous gut flora (6), stored, or utilized. The potential influence of diet on excretion is evident.

Early studies on urinary excretion of carnitine generally ignored diet (7). This may be because the carnitine content of foods was not known and also because Cederblad (8) had shown a greater mean urinary excretion of total carnitine than dietary intake of carnitine (243 vs 190 μmol/d). From her study on one female subject, it appeared that the body's need for carnitine was met by biosynthesis and that the effect of diet was not an important factor to consider. However, several studies have shown that an oral carnitine supplement increases carnitine excretion (9–12). Because of this a few researchers have now controlled for dietary intake of carnitine, placing all their subjects on a specific diet for which the carnitine content had been analyzed (13, 14). However, few have measured the extent to which dietary carnitine influences urinary excretion in a natural setting where subjects are free-living. The purpose of this study was to measure the effect of normal variations in carnitine intake (between subjects) on carnitine status, as exhibited by urinary excretion of total and free carnitine in adult women, and on breast-milk content of the carnitine fractions (free, acid-soluble acyl- acid-insoluble acyl-, and total) in lactating women.

Subjects and methods

Subjects

Sixteen lactating (1–10 mo postdelivery) and 15 control (0 gravida) women from the Washington State University (WSU) locale participated in a study to determine the effect of carnitine intake on carnitine excretion. The subjects were solicited by personal contact, with an attempt to choose control subjects similar to the lactating women in age and body size. They were all considered healthy because none were being treated for any diseases. The study was approved by the Institutional Review Board at WSU and all subjects gave written informed consent.

Dietary intake

The subjects were asked to record everything they consumed for 3 consecutive days (the majority chose weekdays), using household measures for everything except meat, for which they were asked to give the weight (gram scales were provided where

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TABLE 1
Comparison of physical characteristics of control and lactating women*

	Control group (n = 15)	Lactating group (n = 16)	All subjects (n = 31)
Age (y)	27.7 ± 1.3	29.8 ± 1.1	28.8 ± 0.9
Height (cm)	165.8 ± 1.9	164.3 ± 1.5	165.0 ± 1.2
Weight (kg)	63.2 ± 2.7	61.9 ± 1.7	62.5 ± 1.5
Body fat (%)	32.5 ± 1.4	36.0 ± 1.3	34.3 ± 1.0
BMI†	22.9 ± 0.6	23.0 ± 0.7	23.0 ± 0.5
Arm-muscle area (cm^2)	34.3 ± 1.9	28.3 ± 1.0	31.2 ± 1.2

* $\bar{x}$ ± SE.
† Body mass index (kg/m^2).

needed). The lactating women were instructed by a dietitian in their own homes whereas most of the control women were instructed in small groups in the Food Science and Human Nutrition Department at WSU. They were shown how to keep the records, by using a modification of the format from the Western Regional Project W-153 (15). The importance of eating their usual diet was also stressed. The dietitian checked over each completed food record, clarifying any questionable data with the subjects individually. Analysis of their diets for the major nutrients was done by using a US Department of Agriculture (USDA) *Handbook No 8* (16, 17) computer database. The carnitine content of their diets was calculated by using Borum's list of foods for which the carnitine content has been analyzed (PR Borum, personal communication, 1985).

Sample collection and analysis

One complete 24-h urine collection (from the second void after rising through the first void the next day) was obtained on the second or third day of the diet study from all the subjects except one (collected on day 1). Fourteen of the lactating women also provided a single breast-milk sample (15–25 mL) taken at their convenience without pumps during the study. They recorded the day of collecting the sample relative to their 3-d diet record, the time of collection, and whether it was fore or hind milk. The urine and breast milk were collected in opaque polyethylene containers. Anthropometric measures were taken of height, weight, arm circumference, and triceps skinfold thickness. Percent body fat was calculated by the Durnin and Womersley method, based on triceps skinfold thickness (18). Arm-muscle area was estimated by using Gurney and Jelliffe's nomogram, based on arm circumference and triceps fatfold thickness (19). The body mass index (BMI; wt/ht^2 in kg/m^2) was also calculated. Pertinent background information (exercise and sleep habits, date of last menstruation, etc) was gathered from all the subjects by use of a short questionnaire. The infants' growth and feeding practices were also obtained.

Urine samples were kept refrigerated for ~2 d (a few were stored for up to 5 d) before they were filtered, and a sample was frozen for later analysis (within < 5 mo). Breast-milk samples were frozen immediately and stored at −10 °C until analysis (within < 6 mo). Urinary creatinine was measured by using the Technicon AutoAnalyzer (Technicon Instruments Corp, Tarrytown, NY) method (20). Samples of 100 μL urine were hydrolyzed with 1 mol KOH/L in preparation for assay of total carnitine (free plus acid-soluble acylcarnitine), and 100-μL samples of urine were assayed directly for free carnitine. Samples of 200 μL of breast milk were precipitated with an equal volume of perchloric acid (PCA). The urine was analyzed for free and total carnitine; the breast milk for free carnitine, acid-soluble acylcarnitine (primarily short-chain), and acid-insoluble acylcarnitine (primarily long-chain) by using Brass and Hoppel's radiometric assay (21). Thus, carnitine was determined in three fractions: *1*) in the PCA supernatant to estimate free carnitine, *2*) after alkaline hydrolysis of this supernatant to measure total acid-soluble carnitine (free carnitine plus acid-soluble acylcarnitine), and *3*) after alkaline hydrolysis of the PCA pellet to measure acid-insoluble acylcarnitine. The difference between fractions 2 and 1 was an estimate of the amount of acid-soluble acylcarnitine.

The reaction between carnitine and [^{14}C]acetyl-CoA was catalyzed by carnitine acetyltransferase in the presence of 5,5′-dithio-*bis*-(2-nitrobenzoic acid), ethyleneglycol-*bis*-(β-aminoethyl ether)-N,N′-tetraacetic acid, and morpholinopropanesulfonic acid buffer. The mixture of sample and reagents was passed through a Dowex-2 anionic-exchange column (Sigma Chemical Co, St Louis). The eluent was counted with a toluene-Triton scintillant in a Packard Tricarb 460 scintillation counter (Packard Instruments, Downers Grove, IL). Linear standard curves were consistently obtained with a coefficient of variation ≤ 10% between sample duplicates 97% of the time.

Statistical analysis

Multiple regression and analysis of covariance were used to determine the relationship between *1*) dietary and urine carnitine (while accounting for factors such as maternal weight, exercise, and body fat composition) and *2*) milk and dietary carnitine (while considering weeks postpartum, time of milk collection, and maternal weight). Pearson's product-moment correlation was used to determine correlations between the continuous variables. Student's t test was used to identify any significant dietary or physical characteristic differences between the control and lactating groups. All statistical results were obtained by using SAS statistical programs (22). Mean values are reported with SEs throughout this article, unless stated otherwise.

Results

Physical characteristics

Physical characteristics of the lactating and control women were similar (**Table 1**); however, there were dietary intake differences (**Table 2**). The mean consumptions of energy, protein, fat, percent of energy from fat, iron from diet, and total iron as well as dietary carnitine were significantly greater in the lactating group ($P < 0.05$).

Urine

The mean urinary excretions of total and free carnitine (217.2 and 80.2 μmol/d for the control group and 234.6 and 83.8 μmol/d for the lactating group, respectively) were not statistically different between the two groups at $P > 0.05$ (**Table 3**). Urinary-excretion values of total and free carnitine in response to carnitine consumption were also similar for the two groups ($P > 0.05$).

TABLE 2
Comparison of daily dietary intake of control and lactating women*

Dietary component	Control group (n = 15)	Lactating group (n = 16)	All subjects (n = 31)
Carnitine			
(μmole)	288.3 ± 58.6	428.4 ± 47.5†	360.5 ± 38.9
(mg)	46.7 ± 9.5	69.4 ± 7.7	58.4 ± 6.3
Energy			
(kJ)	7 845 ± 519	9 929 ± 510‡	8 920 ± 406
(kcal)	1 875 ± 124	2 373 ± 122‡	2 132 ± 97
Protein			
(g)	73.2 ± 5.7	92.7 ± 5.0§	83.3 ± 4.1
(% energy)	15.6 ± 0.8	15.8 ± 0.5	15.7 ± 0.4
Fat			
(g)	68.0 ± 5.8	101.8 ± 7.3‡	85.5 ± 5.5
(% energy)	31.7 ± 1.1	37.8 ± 1.1†	34.9 ± 0.9
Iron			
From diet (mg)	13.2 ± 1.1	17.6 ± 1.4†	15.5 ± 1.0
Total (mg)‖	23.2 ± 3.3	57.1 ± 7.1†	40.7 ± 5.0
Percent of RDA (%)¶	155 ± 22	381 ± 47†	272 ± 33
Vitamin C			
From diet (mg)	120 ± 13	123 ± 16	121 ± 11
Total (mg)‖	152 ± 16	251 ± 48	203 ± 27
Percent of RDA (%)¶	254 ± 27	268 ± 51	262 ± 29
Vitamin A			
From diet (IU)	7 929 ± 2 291	8 476 ± 950	8 211 ± 1 191
Total (IU)‖	10 262 ± 2 255	15 351 ± 1 673	12 889 ± 1 443
Percent of RDA (%)¶	256 ± 56	241 ± 26	249 ± 30
Calcium			
From diet (mg)	1 083 ± 131	1 224 ± 121	1 156 ± 88
Total (mg)‖	1 154 ± 127	1 540 ± 109§	1 353 ± 89
Percent of RDA (%)¶	125 ± 15	128 ± 9	127 ± 8
Zinc			
From diet (mg)	10.3 ± 0.8	12.6 ± 0.8	11.5 ± 0.6
Total (mg)‖	15.8 ± 2.4	28.0 ± 10.5	22.1 ± 5.6
Percent of RDA (%)¶	131 ± 20	153 ± 56	147 ± 35

* $\bar{x}$ ± SE (from 3-d diet records for each subject).
†‡§ Significantly different from control subjects: †$P < 0.001$, ‡$P < 0.01$, §$P < 0.05$ (pooled t test).
‖ Includes nutrient from supplements as well as from diet.
¶ Total intake as a percent of 1989 recommended dietary allowance (RDA) (23).

TABLE 3
Urinary excretion of free and total carnitine and creatinine in control and lactating women*

Urine component	Control group (n = 15)	Lactating group (n = 16)	All subjects (n = 31)
Total carnitine (μmol/d)	217 ± 35	234 ± 27	226 ± 22
Free carnitine (μmol/d)	80 ± 17	84 ± 18	82 ± 13†
Creatinine (μmol/d)	10.78 ± 0.35	10.60 ± 0.26	10.69 ± 0.17‡
Ratio of total carnitine to creatinine‖	19.45 ± 2.82	22.05 ± 2.37	20.81 ± 1.80
Ratio of free carnitine to creatinine¶	7.12 ± 1.58	7.80 ± 1.69	7.76 ± 1.13

* $\bar{x}$ ± SE. There were no significant differences between control and lactating groups for urine components ($P > 0.05$).
† Correlated with total carnitine for all subjects ($r = 0.94$, $P < 0.0001$).
‡ Correlated with total and free carnitine for all subjects ($r = 0.49$, $P < 0.0005$ and $r = 0.38$, $P < 0.03$, respectively).
‖ Expressed as μmol/mmol.
¶ Expressed as μmol/mmol.

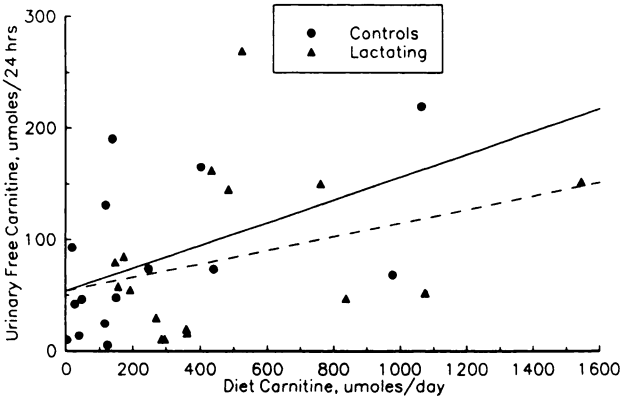

FIG 1. Effect of dietary carnitine on urinary free carnitine in control and lactating women. —— Control, $y = 53.39 + 0.10x$; ------ lactating, $y = 53.67 + 0.06x$.

Subsequent relationships were determined by using all subjects ($n = 31$). Urinary free carnitine (**Fig 1**) and total carnitine (**Fig 2**) exhibited a correlation with dietary carnitine consumed on the day of the urine collection ($r = +0.39$, $P < 0.03$, and $r = +0.45$, $P < 0.01$, respectively) but not with mean 3-d carnitine intake. Subject weight was also related to total carnitine excretion ($P < 0.02$); however, the dietary relationship was still present ($P < 0.01$) even when weight was accounted for in the multiple-regression analysis.

In the urine, total carnitine correlated with free carnitine ($r = 0.94$, $P < 0.0001$) (Table 3). Free carnitine was 31 ± 17% of total carnitine. Subjects with increased urinary carnitine excretion had a higher proportion of free carnitine, whereas those with low carnitine excretion had a smaller proportion of free carnitine. Creatinine was also correlated with urinary total and free carnitine ($r = 0.49$, $P < 0.005$ and $r = 0.38$, $P < 0.03$, respectively) in a complete 24-h collection (Table 3).

There was no effect of exercise on urinary carnitine; the five subjects who had a planned exercise program (ie, jogging, cycling, aerobic dancing, or vigorous walking for 30–60 min/d) did not respond differently from the other subjects (data not shown). A determination of the effect of ovulation on urinary carnitine excretion was limited because only 2 of the 31 subjects were near the midpoint of their menstrual cycle during the urine collection.

TABLE 4
Fractional carnitine composition of breast milk from 14 lactating women

	$\bar{x}$ ± SE	Range
	μmol/L	
Total carnitine	44.97 ± 3.13	28.01–72.18
Free carnitine	36.52 ± 2.28	22.68–56.25
Short-chain carnitine	6.01 ± 0.91	0–11.94
Long-chain carnitine	2.43 ± 0.29	1.28–5.25

Milk

Table 4 presents the mean breast-milk content of the various carnitine fractions of 14 lactating women. Dietary carnitine had no effect on any of the carnitine fractions of breast milk; also, the age (**Fig 3**) or growth of the infant, whether he or she consumed other foods, the time of milk collection, and maternal carnitine excretion in the urine had no relationship to the carnitine composition of the milk. Carnitine in breast milk was mostly in the free form ($\bar{x}$ of 81%). Free carnitine did not correlate with any of the infant, maternal, or dietary factors; however, acid-soluble and acid-insoluble acylcarnitine and total carnitine were related to maternal body weight and BMI (**Table 5**).

Diet

Dietary carnitine intake was positively related to food zinc, protein, iron, and fat (without supplements; $r = +0.69$, $+0.61$, $+0.52$, $+0.47$, respectively) (**Table 6**). Urinary carnitine output, however, was only related to dietary carnitine and protein (Table 6, **Figs 4 and 5**).

Discussion

The urinary free and total carnitine measured in this study are compatible with values reported by others (9, 11, 12, 24) for adult women. Hoppel and Genuth (14) reported lower concentrations of free carnitine; however, their study diet was very low

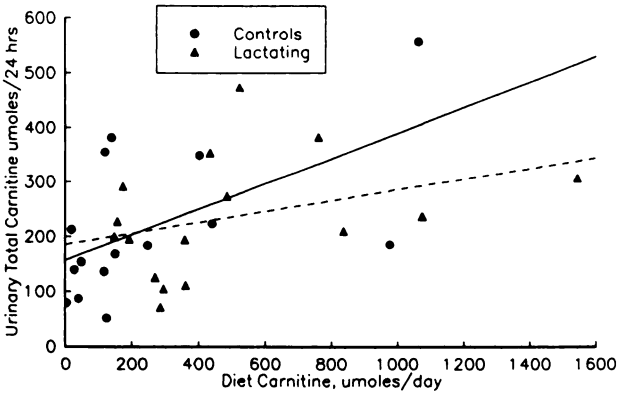

FIG 2. Effect of dietary carnitine on urinary total carnitine in control and lactating women. —— Control, $y = 156.2 + 0.23x$; ------ lactating, $y = 185.29 + 0.10x$.

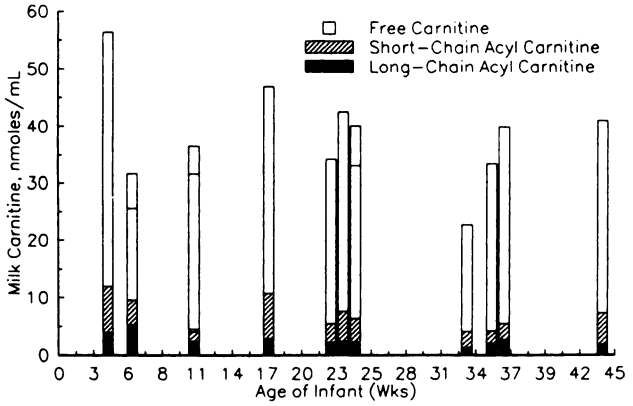

FIG 3. Relationship of infant age to the carnitine fractions of breast milk in 14 lactating women.

TABLE 5
Relationship between maternal characteristics (body weight and body mass index) and fractional carnitine components of breast milk from 14 lactating women

	Maternal weight		Body mass index	
Carnitine component	*r*	*P*	*r*	*P*
Free carnitine	0.46	0.10	0.47	0.09
Acid-soluble acylcarnitine	0.73	0.002	0.59	0.025
Acid-insoluble acylcarnitine	0.83	0.0002	0.63	0.015
Total carnitine	0.61	0.02	0.57	0.03

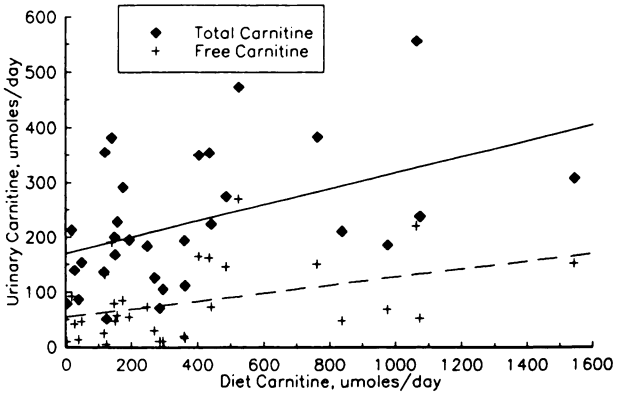

FIG 4. Relationship of dietary carnitine to urinary total and free carnitine. —— Total, $y = 170.1 + 0.15x$; - - - free, $y = 54.62 + 0.07x$).

in carnitine, which could explain the decreased concentration. We also had subjects who excreted very low amounts of free carnitine in their urine (as low as 5–10 μmol/d) and attribute this to their low dietary intake of carnitine. Some of our subjects were lactoovovegetarians; Lombard et al (25) showed that lactoovovegetarian females excreted 33% of the total carnitine excreted by women on a mixed diet.

Unlike Cederblad (8), who found that carnitine excretion was greater than intake for her one subject, 19 of our 31 subjects excreted less carnitine than they consumed. Rebouche and Engle (24) reported that 8 of their 11 subjects excreted less than they consumed, indicating that diet is important in carnitine metabolism.

We found a 62.7 ± 10.1% ($\bar{x}$ ± SE) excretion in urine of the carnitine consumed on the day of collection. The significant correlation between urinary carnitine and dietary carnitine on the day of the urine collection, but not the mean intake of the 3 d, indicates that there is an almost immediate response to diet. This response is in agreement with Hoppel and Genuth's (14) study, where urinary free carnitine excretion decreased rapidly from 36 μmol/d on the first day to 6 μmol/d on the second day of a low-carnitine diet (Ensure; Ross Laboratories, Columbus, OH). The fact that the mean urinary concentration of total carnitine in our study was only ~63% of dietary carnitine consumed that day supports the theory suggested by Rebouche and Engle (24) that carnitine degradation does occur in the gastrointestinal tract of humans.

Of a 2-g dose of L-carnitine ingested, Bach et al (13) found that 7 ± 1% was excreted during the next 24 h. This is equivalent to an increase of 864 ± 123 μmol/d ($\bar{x}$ ± SE) from a control mean of 308 μmol total carnitine/d. The large variation in response to the same dose and amount of dietary carnitine (100 mg) might have been due to variation in carnitine status among subjects as well as to the inclusion of both male and female subjects in their study. Although Bach et al considered their dose physiological, it would be difficult to consume 2 g of carnitine in a normal diet [it would take 1.6 kg (3.5 lb) of steak to provide this amount of carnitine]. Maebashi et al (12) reported a 65.5% mean recovery rate when he administered a 200-mg dose of L-carnitine to five adults. Unfortunately, neither the dietary carnitine nor a measure of variation was reported. Rebouche et al (6) showed that gut degradation of carnitine occurs in rats, producing carnitine metabolites (primarily trimethylamine N-oxide) in the urine. He found that up to 23% of an oral dose of L-[methyl-^{14}C]carnitine (86 nmol) was accounted for by these metabolites.

The amount of total carnitine that we measured in human milk is very close to that reported by Schmidt-Sommerfeld et al (26) (45.2 ± 5.3 μmol/L) from mothers whose infants were ≥ 1 mo old. They also found no correlation with time postpartum and carnitine concentration (after the first month). Sandor et al (27) reported a lower mean value of 35.2 μmol/L by the sixth to seventh week of lactation; however, their figures were also lower than those of Warshaw and Curry (28) for milk collected the first week postpartum (56–70 vs 70–95 μmol/L). Penn

TABLE 6
Relationships between dietary constituents (3-d average) and dietary or urinary carnitine*

Dependent variable	Independent variable	Regression	*r*	*P*
Dietary carnitine (μmol/d)	Dietary zinc (mg/d)	$y = -147.2 + 44.1x$	+0.69	<0.0001
	Dietary protein (g/d)	$y = -119.98 + 5.77x$	+0.61	<0.0003
	Dietary iron (mg/d)	$y = 38.4 + 20.8x$	+0.52	<0.003
	Dietary fat (g/d)	$y = 76.1 + 3.33x$	+0.47	<0.007
Urinary total carnitine (μmol/d)	Dietary carnitine (μmol/d)	$y = 170.1 + 0.15x$	+0.45	<0.01
	Dietary protein (g/d)	$y = 31.37 + 2.34x$	+0.44	<0.01
Urinary free carnitine (μmol/d)	Dietary carnitine (μmol/d)	$y = 54.62 + 0.07x$	+0.39	<0.03
	Dietary protein (g/d)	$y = 15.72 + 1.17x$	+0.39	<0.03

* $n = 31$.

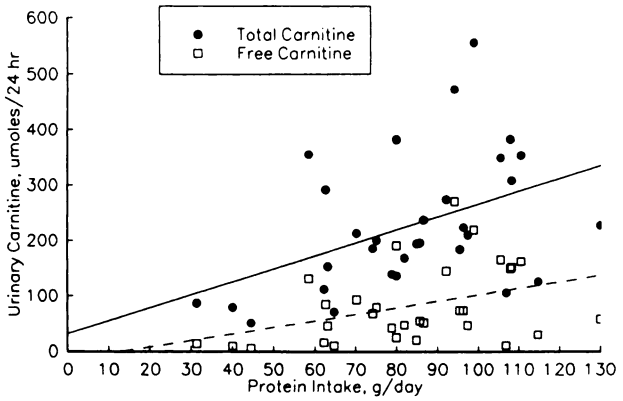

FIG 5. Relationship of dietary protein to urinary total and free carnitine. —— Total, $y = 31.37 + 2.34x$; -·-·-·- free, $y = -15.72 + 1.17x$).

et al (29) found that the concentration of long-chain acylcarnitine in human milk was < 1% of total milk carnitine, whereas we found that long-chain acylcarnitine was ~5% of total carnitine. Use of a breast pump by the subjects in the Penn et al study might account for some of the difference. However, the milk-extraction procedures for carnitine analysis have also varied among studies. Milk carnitine has been measured after sonication and after milk-fat removal by centrifugation (30) with chloroform-methanol extraction (29) and direct PCA precipitation (this study). We have no values from different extraction methodologies to compare using these milk samples; to determine the true source of discrepancies, we should reevaluate the procedure's extraction step.

Lactation does not seem to have an effect on urinary excretion of carnitine. This may be because the increased maternal need of carnitine for secretion in milk appears to be small and therefore could easily be met through the diet. On the basis of an average volume of milk consumption (for a 4-mo-old infant at the 50th percentile of growth), daily carnitine secretion in breast milk would be 800 mL milk/d (31) times 45 μmol carnitine/L milk, which equals 36 μmol, or 6 mg, carnitine/d. Such a small amount would make it difficult to detect a difference between lactating and control women in their urinary response to diet carnitine.

Mammary excretion of carnitine appears to be independent of dietary carnitine intake not only because no correlation was found between dietary and breast-milk carnitine but also because there were three lactating subjects whose excretion of carnitine in urine alone was greater than their intake, attributable to the body's ability to synthesize carnitine from lysine and methionine or to release carnitine stores via muscle catabolism. This independence is not surprising because the overall nutrient composition of breast milk is very constant, despite variation in maternal diet. This is exhibited by the fact that even poorly nourished mothers produce milk of good nutritional quality, although of limited quantity (32).

Novak et al (33) showed that there are decreased plasma concentrations of free and acetyl carnitine in infants 1–10 wk old who were fed soybean-formula diets (carnitine free), suggesting a need for exogenous carnitine. However, the effect of low plasma concentrations in infants has yet to be described. If carnitine is needed for the newborn, it may also be important throughout infancy because the carnitine concentration in breast milk is fairly constant beyond 4 wk of lactation.

Although urinary carnitine and creatinine were correlated, measurement of creatinine alone as an estimate of carnitine would not be acceptable because of the large variation in that relationship (CV for the ratio of total carnitine to creatinine, 50%; CV for the ratio of free carnitine to creatinine, 82%). Although somewhat affected by exercise; dietary creatine and creatinine from meat and fish, fasting, and other factors, creatinine excretion is still considered a good indicator of muscle mass (1 g creatinine equals 20 kg muscle mass) (34). It would then be reasonable for carnitine and creatinine to be correlated because skeletal muscle is the major store of carnitine. Cederblad et al (11) obtained results that suggested a relationship between urinary carnitine excretion and muscle mass.

Maebashi et al (12) found that during ovulation urinary carnitine more than doubled in the one woman he studied. Of our two subjects potentially in this category, neither had elevated carnitine concentrations in their urine.

On the basis of the results of this study, we can say that the urinary excretion of carnitine is influenced by dietary intake of carnitine as well as protein intake and other undefined factors and that diet should be controlled or at least assessed when carnitine is being studied in humans. Also, because we had several healthy, active subjects with urinary total carnitine concentrations < 100 μmol/d, those with low carnitine excretions should not necessarily be considered impaired in carnitine status. For instance, Tanphaichitr et al (35), who found that malnourished Thai subjects excreted a mean of only 127 ± 18 μmol/L total carnitine in their urine (vs 161 ± 19 μmol/L for their healthy counterparts), concluded their article by saying, "The effects of impaired carnitine status in Ubol adults are now under the investigation." The assumption that low carnitine concentrations in urine and blood indicate impaired carnitine status cannot be made until well-controlled balance studies are conducted in which clinical symptoms and biochemical indices of carnitine deficiency are identified.

We gratefully acknowledge the use of tables of carnitine content of foods shared with us by Peggy Borum, University of Florida, Gainesville, FL.

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