~~APPENDIX V-b~~

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Utilization of Potato in the Dietary Treatment of Infants With Malnutrition of Acute Diarrhea

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SUBJECT:

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ABSTRACT

Diets in which white potato provided up to 50% of total energy and 60% of total protein were used to treat 19 children ages 4 to 31 months with second (n=2) or third (n=17) degree protein-energy malnutrition (PEM). Three children with kwashiorkor and its complications responded poorly and were dropped from the study. Rate of recovery and the intake required to sustain steady weight gain in the other sixteen children were comparable to results from a parallel study using wheat pasta and to those previously obtained when a casein, sucrose, vegetable oil formula was fed. Balance studies carried out as intake was increased documented improved apparent N absorption and retention up to intakes of 100 Kcal/kg body wt/day. At that intake and thereafter apparent N absorption was approximately 75%, apparent N retention between 30% and 40% of intake. A similar diet was used to treat 13 acute diarrheal episodes in 12 relatively well-nourished children. All tolerated the diet well and recovered uneventfully. The white potato can provide a substantial part of energy and protein in diets used to treat PEM and acute diarrhea.

Dietary treatment is a cornerstone in the management of both protein-energy malnutrition and acute diarrhea (1). This therapy is ideally accomplished with milk or, in the case of lactase deficiency, with lactose-free formulas (2). The reasons for this practice are the high nutritional value of milk and its easy administration to infants and young children who are more frequently and severely affected by these two interrelated diseases. Nevertheless, the relatively high cost and the lack of availability of milk or lactose-free formulas in developing areas of the world present a problem for those countries in which protein-energy malnutrition and acute diarrhea are most prevalent.

Previous studies in our unit have shown that potatoes could provide a substantial part of the daily requirements of both protein and energy for infants and small children (3). In subsequent studies infants and young children past the acute phase of recovery from malnutrition sustained an adequate rate of growth and maintained normal serum albumin concentrations while consuming diets in which potato provided 50-75% of total energy and 60-80% of total protein for a period of three months (4).

Having as an ultimate goal the demonstration that diets made from inexpensive and easily available products can be used effectively in the treatment of protein-energy malnutrition and acute diarrhea, we modified our usual regimen of formula feeding (1) by the early addition of potato to reach up to 50% of the total calorie intake in these patients. The results of our experience are reported here.

SUBJECTS AND METHODS[1]

Recovery from Malnutrition

Nineteen Peruvian Mestizo children with moderately severe or severe protein-energy malnutrition entered into the study on the day of their admission to the Instituto de Investigacion Nutricional (Nutrition Research Institute) in

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[1] These studies were approved by the Joint Committee on Human Investigation, The Johns Hopkins Medical Institutions and the corresponding committee of the Instituto de Investigacion Nutricional, Lima, Peru. Informed consent was obtained from the parents of all children participating in the studies.

Lima, Peru. Selected indicators of their clinical and nutritional status are presented in Table I.

The initial management of these patients was that routinely used in our unit (1). This essentially consisted of careful handling of fluid and electrolyte problems, aggressive treatment of documented or suspected infections, and nutritional therapy based primarily on oral feeding.

Dietary therapy is started as soon as possible with glucose electrolyte solution (GES) and continued for no more than 24-36 hours; this is usually followed by a casein-sucrose-vegetable oil diet that provides 8% of the calories as protein (N x 6.25), 48% as fat and 44% as carbohydrate. Vitamin and mineral mixtures are added to meet Recommended Dietary Allowances (United States) (5). This formula is initially fed at 25 Kcal/kg body wt/day in a volume sufficient to meet fluid requirements, usually 125-150 ml/kg/day. Progression of the diet to higher calorie intakes is usually made every one or two days in increments of 25 Kcal/kg/day if stool output is less that 100-150 g/day and the consistency of feces is improving; total volume of the diet is held constant until a concentration of 1 Kcal/ml is reached, when further increases in intake are achieved by increases in the volume offered. This progression is continued until acceptable weight gain ensues.

In the present study there were two dietary groups. The initial nine patients, diet group 1, received only the casein-based diet until they reached an intake of 75 Kcal/kg/day; thereafter all calorie increments were accomplished with potato flour (Table II). Once it was clear that patients recovered successfully with this regimen, diet group 2 was started. The ten patients in this group received the casein-based diet up to a level of 50 Kcal/kg/day; thereafter further increments were provided by potato flour, to a maximum of 50% of the total calorie intake (Table II). In each group the study was terminated when the patients were gaining weight steadily for a period of seven days.

To avoid the problem of variability, potato flour was prepared from a single batch of cooked, oven-dried mariva potatoes (solenum tuberosum ssp. andigeno). Preliminary studies showed no differences in digestibility when compared to fresh or lyophilized potatoes (3). Protein content of the dehydrated material was 8.32 g/100 g.

The patients in both dietary groups were clinically comparable with the exception that there were three patients with kwashiorkor in diet group 2 and only one in diet group 1. When patients in group 1 and group 2 reached a calorie intake of 75 Kcal/kg/day and 50 Kcal/kg/day respectively, balance studies of at least two days duration were carried out at each subsequent level of calorie intake, using methods standard for our unit (6). Diets were analyzed for nitrogen, energy, sodium and potassium contents at each level of intake to ascertain that they were prepared correctly. Fecal wet and dry weight, nitrogen and fat were determined using standard techniques (7-8). Serum total protein (Biuret) and albumin (acetate gel electrophoresis) concentrations were monitored at approximately weekly intervals.

Dietary Management of Acute Diarrhea

Twelve male patients in long-term recuperation from malnutrition who developed acute diarrhea, defined as semiliquid or watery stools in an amount equal or greater than 50 ml/kg/day, were admitted to the study. Their weights and lengths were below those expected for their chronological ages using the NCHS reference population, but weights for lengths and the serum albumin concentrations were normal. Selected indicators of their clinical status are presented in Table III. Weights recorded are those taken the day prior to the development of diarrhea. The percentage of dehydration was calculated by differences between the pre-diarrhea weight and the weight on admission to the study. Fecal weights were measured by metabolic collections.

Stool cultures for salmonella and shigella were obtained from all patients, but at that time our laboratory was unable to identify other intestinal pathogens such as enterotoxigenic E. Coli, enteropathogenic E. Coli or rotavirus.

The management of acute diarrhea in our unit includes careful handling of fluid and electrolyte problems, with early gradual reintroduction of food; antibiotics are rarely indicated. Usually patients are hydrated orally with glucose electrolyte solutions. The intravenous (IV) route is used if moderate or severe dehydration is present or in those cases in which it is not certain that adequate oral intake will be maintained. Refeeding is started with a formula at 25 Kcal/kg/day; this usually occurs during the 2nd or 3rd day after the beginning of diarrhea. Calorie intake is advanced as described above for the management of malnutrition.

In the present study, the patients followed this routine until they reached a calorie intake of 25 Kcal/kg/day;

starting with a calorie intake of 50 Kcal/kg/day and thereafter potato flour was added to provide half of total energy. Diets were prepared similarly to those used in the management of malnutrition, protein (casein + potato, N x 6.25) supplying 8% of calories.

The patients received each level of calorie intake for 1-3 days, depending on stool volume and consistency. If a child's stools became formed at lower levels of intake, his diet was advanced more rapidly by skipping a level, for example, from 50 Kcal/kg/day to 100 Kcal/kg/day. Patients were considered clinically recovered when they reached and tolerated a calorie intake that allowed them to gain weight regularly with normal stool volume and consistency. The study was terminated when the children reached their previous calorie intake.

Serum total protein and albumin concentrations were monitored at weekly intervals. Metabolic balance studies were done at each level of calorie intake to determine fecal wet and dry weight, absorption of nitrogen, fat and carbohydrates, and apparent nitrogen retention. These results were compared with those of a previous study (3), in which protein quality and digestibility of white potato were evaluated with potatoes providing 50% of calorie intake in a similar group of patients without diarrhea or malabsorption who were consuming 100-125 Kcal/kg/day.

RESULTS

Recovery from Malnutrition

All patients in group 1 and seven of the ten patients in group 2 tolerated the diets well and completed the study. Most patients were tolerating 25 Kcal/kg/day on the 2nd hospital day, 75 Kcal/kg/day on the 5th day and 100 Kcal/kg/day on the 9th day. They needed 100-125 Kcal/kg/day to start gaining weight regularly, and this usually occurred around the 10th day of hospitalization (Table IV).

The mean serum albumin concentration diminished progressively in both groups (Table IV). This decrement may have been in part artifactual in group 1, because of the tendency to measure albumin concentrations more frequently in the patients with kwashiorkor. Of the seven patients in group 2 that completed the study, five manifested decreases of their serum albumin. This occurred despite the fact that their apparent absorption and retention of nitrogen were over 70% and 30% of intake respectively and that they appeared to

be recovering without overt clinical problems. Two of them (#'s 590 and 598) were subsequently found to have had giardia that was undetected in three initial stool samples.

There were no significant differences between group 1 and group 2 in the results of the metabolic studies. The combined results for both dietary groups are presented in Table V. Fecal wet and dry weights increased with higher calorie intakes and the higher proportion of potato in the diet. Apparent nitrogen absorption and retention were below 72% and 30% respectively at the lower levels of calorie intake. Once calorie intakes reached 100 Kcal/kg/day and thereafter nitrogen absorption was close to 75% and nitrogen retention was between 30-40%. Fecal excretion of energy was 9-12% of intake, that of fat 1-2 g/day, and that of carbohydrate 5-10% of intake, at the higher levels of calorie intake (100-150 Kcal/kg/day).

There were three patients in group 2 in whom the study was discontinued, all of them were severely ill patients with kwashiorkor with a combination of at least two of the following problems: persisting diarrhea with dehydration, sepsis, progressive hypoalbuminemia or severe steatorrhea (>35% of fat intake). All of them recovered subsequently with specialized formulas (Pregestimil, Portagen).

Dietary Management of Acute Diarrhea

All of the 12 patients, representing a total of 13 diarrheal episodes, recovered uneventfully following the protocol that included 50% of calorie intake provided by potatoes starting with the 50 Kcal/kg/day diet. Six patients received I.V. fluids initially, and all received GES for 1 to 3 days. Most patients were tolerating calorie intakes of 25 Kcal/kg/day on the 3rd hospital day, 50 Kcal/kg/day on the 5th hospital day and 100 Kcal/kg/day on the 7th hospital day. The number of days needed to start gaining weight regularly was 6.9±2.1, this usually occurred while consuming 75 Kcal/kg/day. The number of days needed to reach the previous level of intake was 10±3.2. The mean final albumin concentration was 3.8±0.4 g/dl with all values above 3.4 g/dl.

DISCUSSION

Vegetable foods are the cheapest sources of energy and protein around the world. White potato is the fourth leading world food crop, after wheat, rice and maize. The present

studies show that infants and young children with severe protein-energy malnutrition (PEM) or acute diarrhea are able to tolerate and utilize diets with up to 50% of calorie intake provided by potato during the initial phase of recovery if the diet includes a high quality source of protein to compensate for deficiencies of essential amino acids (10). The number of days needed to reach specific levels of intake and the intakes needed to begin consistent weight gain were comparable to results with a casein-sucrose-vegetable oil diet used for the initial treatment of PEM (Table IV) (1) and to results from a parallel study in which casein and wheat pasta were fed (11).

Since all three patients in whom the study was aborted had kwashiorkor, there is a question about the ability of severely protein-depleted patients to recover on such a diet. Other patients with kwashiorkor, however, recovered without problems. The patients in whom the study was discontinued were either septic, had persistent diarrhea, or had steatorrhea, which suggests that they may represent a group of patients that would develop problems independently of the diet they are fed due to the severity of their disease.

The decrement of the serum albumin concentration in some patients is also worrisome. Clinical, anthropometric and dietary data of patients with decreasing (n=8) and increasing (n=4) albumin concentrations were compared. Patients who experienced a decrease in their serum albumin concentration tended to be younger (7.6±2.9 vs. 11.8±4.5 months), to have a higher albumin on admission (3.78±0.46 vs. 3.28±0.3 g/dl) and to gain weight at a higher rate (10.1±3.28 vs. 6.92±1.73 g/kg/day). None of these differences was statistically significant.

Since the protein quality of potato is inferior to that of animal sources and has a relative deficiency of the sulfur-containing amino acids (12), it is tempting to blame the potato diets for the changes. The deficit in sulfur-containing amino acids should have been compensated for by the casein in the diet. In a previous study recovered malnourished children maintained normal serum albumin levels while consuming diets with half of the calories provided by potato (4). Previous data from our unit (1) documented that it took 53±32 days for the serum albumin value to reach 3.6 gm/dl in children with marasmus and marismic-kwashiorkor fed casein. Thirteen patients from this previous study (1) that were clinically similar to the current patients and who had recovered with the casein-based diet were selected for comparison. Their initial serum albumin concentration was

3.47±0.5 g/dl, that at 5-18 days was 3.21±0.3 and that at days 19-25 was 3.0±0.4 g/dl. Some decrement of the serum albumin concentration early in recovery appears to be an expected finding.

Since we did not identify all the etiologic agents in the cases of acute diarrhea, we cannot be certain that the diets used would be useful for nutritional treatment of all cases of diarrhea, but it is likely that the currently recognized more frequent etiologic agents of diarrhea (rotavirus, enterotoxigenic E. coli) were represented among our patients who successfully recovered.

The results of the metabolic balance studies in patients with PEM and acute diarrhea demonstrate good use of protein, fat and carbohydrate at levels of intake of 100 Kcal/kg/day or more and are comparable to those obtained in previous studies of wheat-casein-vegetable oil diets (11) and to those with our usual casein-sucrose-vegetable oil diet (1). There was increasing carbohydrate excretion in association with increasing intakes of the staple, as described in the wheat-casein study (11).

These data suggest that potato-casein mixtures are as good as casein formulas for the nutritional treatment of patients with PEM or acute diarrhea. Considering our final objective, it would have been desirable to introduce potato into the diet at the beginning of refeeding and to use whole milk rather than casein as the source of animal protein. We chose not to do this because of initial concerns that potato might not be tolerated and that latose in the diet might prove to be a confounding variable in the interpretation of any intolerance that developed. It is likely that both groups of patients would tolerate potato-containing diets from the outset of refeeding, and that the casein could be replaced by small amounts of whole milk, without a significant risk to patient, depsite the potential problem of lactose malabsorption. Other investigators have documented that known lactose malabsorbers can both tolerate and derive significant nutritional benefit from small amounts of milk added to their diets (13).

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Table I

Clinical status of malnourished children on the day of admission

Pt. No.	Age (mos.)	Weight (gm)	Length (cm)	Weight/Age* %	Length/Age* %	Weight/Length* %	Albumin (gm/dl)	Diagnosis**	Complications
Diet Group 1									
570	26.4	7200	71.7	55.3	80.3	80.8	3.73	M	Otitis
571	11.4	6370	68.5	64.3	85.9	78.6	2.89	MK	Diarrhea, Otitis
574	5.1	3440	56.2	47.1	85.2	74.7	3.80	M	Diarrhea
575	7.1	3100	55.1	37.3	79.2	72.0	3.46	M	Otitis, URI
578	7.7	3470	57.4	39.4	80.8	69.4	4.07	M	Diarrhea
579	15.7	7780	73.0	70.0	90.7	83.6	2.12	K	Pneumonia, Giardia
580	6.7	5420	59.5	69.4	87.7	98.5	3.51	M II	Diarrhea
583	9.0	6080	68.0	66.0	94.0	76.0	3.26	M II	Diarrhea, URI
584	8.9	5150	6.18	55.9	85.4	83.0	4.19	M	Diarrhea, URI
Diet Group 2									
533***	31.0	7990	81.6	57.9	87.7	71.3	2.29	K	Chronic Diarrhea, Dehydrated?, Sepsis (day 9)
585	18.5	7620	78.0	66.3	94.7	72.6	3.58	MK	Diarrhea, Otitis
586	8.8	2750	54.8	29.9	75.8	63.9	2.72	M	Diarrhea, URI
587	3.9	3000	54.2	46.9	85.1	73.2	4.27	M	Diarrhea, Steatorrhea
589***	12.7	6510	72.4	62.6	93.8	70.7	2.33	K	Diarrhea, Progressive Hypoalbuminemia
590	6.9	3310	56.8	42.9	84.0	68.9	3.75	M	Giardia, Steatorrhea
594***	28.2	8750	73.2	65.8	80.6	94.1	1.67	K	Sepsis: Staph Aureus (day 4)
596	7.0	5050	64.0	60.8	92.1	74.3	4.18	M	Diarrhea, Steatorrhea
598	14.2	4860	57.8	45.4	73.8	95.3	3.95	M	Diarrhea, Giardia
599	12.8	5730	66.5	55.1	86.1	75.4	2.80	M	Diarrhea, Giardia

* Based on the U.S. National Center for Health Statistics Growth Standard (14).

** Diagnosis: M = Marasmus third degree; M II = Marasmus second degree; MK = Marasmic-kwashiorkor; K = Kwashiorkor, based on the McLaren Score (15).

*** Patients in whom study was discontinued.

Table II

Composition (amount/kg body weight/day) of diets used in initial treatment of malnourished children

Level of Intake (Kcal/kg/d):	25	50	75		100		125	
Dietary Group	1 & 2	1 & 2	1	2	1	2	1	2
Potato g/kg/d	--	--	--	7.14	7.14	14.28	14.28	17.84
Casec* g/kg/d	0.58	1.16	1.74	1.06	1.74	0.94	1.74	1.18
Oil** ml/kg/d	1.5	3.0	4.50	2.33	4.50	3.06	4.50	3.85
Sucrose g/kg/d	2.75	5.5	8.25	6.91	8.25	5.58	8.25	6.92
Total Energy (Kcal/kg/d)	25.00	50.00	75.00	75.00	100.00	100.00	125.00	125.00
Total Protein (N x 6.25) (g/kg/d)	0.5	1.0	1.5	1.5	2.1	2.0	2.7	2.5
Energy provided by Potato (Kcal/kg/d)	--	--	--	25.0	25.0	50.0	50.0	62.5
Protein provided by Potato (g/kg/d)	--	--	--	0.59	0.59	1.2	1.2	1.5

Sodium and potassium are provided at 2 and 3 mEq/kg/day respectively except in patients with kwashiorkor, for whom 5 mEq/kg/day of potassium are provided.

* Mead Johnson, Evansville, Indiana, 1.88 g Casec provides 1.6 g Casein.

** Mixture of cottonseed and soy oil (80:20).

Table III

Clinical status of malnourished children on the day of admission

Pt. No.	Age (mos.)	Weight* (gm)	Length (cm)	Weight/Age %	Length/Age %	Weight/Length %	Albumin (gm/dl)	Na mEq/L	K mEq/L	CO mEq/L	% Dehydration	Fecal wet weight gm/d
575	12.2	6690	63.5	65.5	83.4	99.8	4.47	128	3.9	14.8	6.2	530
576	14.6	6400	64.0	59.2	80.6	94.1	4.07	133	4.5	15.7	5.1	460
580	9.4	7180	65.6	78.0	90.7	98.4	3.96	130	4.7	12.5	6.8	570
582	28.5	11200	80.7	83.5	88.8	101.8	4.28	134	4.3	19.0	2.7	1080
584	10.5	5680	62.0	58.6	83.7	91.6	3.93	134	5.3	19.9	2.0	440
	12.5	6620	63.8	64.2	83.3	97.4	4.75	133	3.5	18.1	2.5	490
594	31.0	10680	76.0	77.4	81.7	106.8	4.08	137	3.6	18.3	6.3	820
595	12.0	5620	63.2	55.0	83.0	86.5	4.35	---	---	---	2.6	310
596†	10.8	7700	70.6	77.7	94.3	88.5	3.86	---	---	---	---	360
599	16.8	8640	71.8	76.5	88.2	94.9	3.77	139	3.6	10.7	2.0	590
601†	5.5	4130	56.1	55.0	82.7	89.8	3.91	140	4.0	16.8	4.3	270
605	11.5	6570	63.0	65.7	83.3	101.1	3.61	144	3.8	---	5.0	550
606	4.2	3780	54.0	56.4	84.7	92.2	3.44	---	---	---	---	400

* Weight before diarrhea.

†Shigella species were isolated in stool cultures.

Table IV

Recovery of malnourished infants with casein-potato diets†

		Group 1 (n=9)		Group 2 (n=7)	Casein-Wheat (11) (n=11)	Casein (1)* (n=37)
Days required to reach intake of:						
25 Kcal/kg/d		1.5±0.5		1.8±1.0	2.6±1.5	3.5± 5.1
50 Kcal/kg/d		2.7±1.0		3.1±1.3	4.4±1.5	3.5± 5.1
75 Kcal/kg/d		4.2±1.6		5.3±1.7	7.1±2.3	7.9± 5.1
100 Kcal/kg/d		8.6±2.7		8.1±1.9	10.4±2.2	10.5± 6.0
125 Kcal/kg/d		12.7±2.9		10.0±0.7	14.0±3.2	14.7± 6.9
150 Kcal/kg/d		19.5±1.5		14.2±2.7	19.8±6.1	28.0±23.0
Days required to establish consistent weight gain for 7 days:		11.5±1.9		9.7±3.1	10.8±4.2	18.0
Calorie intake to begin consistent weight gain (Kcal/kg/day)		108±17		107±32		
Serum Ablumin (g/dl)	(n)		(n)			
Day 1	(9)	3.45±0.62	(7)	3.60±0.62		
Day 5-11	(6)	3.46±0.47	(7)	3.27±0.52		
Day 12-18	(5)	3.24±0.72				
Day 19-25	(4)	3.06±0.49	(7)	3.09±0.54		

* Casein, sucrose, vegetable oil diet used routinely in our unit for the management of chronic diarrhea and malnutrition. Since most of the patients in the present study were considered marasmic or marasmic-kwashiorkor, only these type of patients are considered for comparison purposes.

† Data presented are means±standard deviation.

Table V

Rate of weight gain, fecal weight, apparent absorption and retention of nitrogen and fecal excretion of energy, fat and carbohydrate by level of dietary intake in children recovering from malnutrition with casein-potato diets†

Level of Energy Consumption		Days on Diet	Weight Gain	FECAL WEIGHT		NITROGEN		FECAL EXCRETION		
				Wet	Dry	Absorption	Retention	Energy	Fat	Carbohydrate
Kcal/kg/d	(n)		g/kg/d	g/d	g/d	%	%	% Intake	g/d	% Intake
50	(6)*	2.1±0.4	-9.9±7.5	92±53	7.8±3.9	51.1±16.0		12.0±3.9	1.0±0.4	7.6±11.7
75	(16)	3.8±2.2	1.0±6.2	74±29	9.4±4.0	71.8± 8.5	29.3±10.5	11.8±5.8	3.1±2.4	3.6± 2.7
100	(16)	5.4±5.0	8.2±8.5	90±46	11.1±5.8	74.9± 6.8	31.7±11.3	9.5±2.8	1.8±1.3	4.9± 3.0
125	(15)	5.3±2.9	9.1±4.6	122±39	13.7±4.2	75.2± 8.6	38.5± 9.4	10.0±4.0	1.8±1.3	6.1± 2.5
150	(8)	6.0±3.7	7.8±4.1	180±88	18.0±6.4	73.8± 9.5	38.0± 9.8	12.0±6.6	1.7±1.2	9.8± 4.9

* Only group 2 patients.

† Data presented are means±standard deviations.

Table VI

Rate of weight gain, fecal weight, apparent absorption and retention of nitrogen, and fecal excretion of energy, fat and carbohydrate by level of dietary intake in children recovering from acute diarrhea*

Level of Energy Consumption kcal/kg/d		Days on Diet	Weight Gain g/kg/d	FECAL WEIGHT		NITROGEN		FECAL EXCRETION		
				Wet	Dry	Absorption	Retention	Energy % Intake	Fat g/d	Carbohydrate % Intake
25	(n= 9)	1.7±0.6	-26.0±14.0	123±86	6.3±3.6	49±27		15±8	1.1±1.0	2.5±2.7
50	(n=10)	1.6±0.5	0.7±9.0	45±40	5.8±4.6	77±11	5± 9	8±5	1.0±0.8	5.0±2.5
75	(n= 8)	1.5±0.5	9.6±4.2	58±44	7.8±5.2	84±11	31±15	6±4	0.9±0.7	4.6±2.7
100	(n=10)	1.6±0.5	9.0±7.5	103±58	14.3±7.1	79± 5	38± 7	8±3	1.3±0.7	6.9±1.2
125	(n=11)	2.3±0.8	12.3±6.8	146±63	18.5±5.6	81± 6	43± 8	9±2	1.3±0.7	7.7±1.2
150	(n= 6)	2.7±0.5	0.1±8.9	167±46	20.0±4.2	79± 2	45± 4	10±1	1.7±0.8	8.7±1.2

* Data presented are means±standard deviation.