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Nutritional Effects of Supplementing Liquid-Formula Diet with Dietary Fiber on Elderly Bed-Ridden Patients

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Wada, S., Nakaji, S., Umeda, T., Takahashi, I., Oyama, T., Chinda, D., Sugawara, K., Shimoyama, T., Sakamoto, S., and Fukuda S. *Nutritional Effects of Supplementing Liquid-Formula Diet with Dietary Fiber on Elderly Bed-Ridden Patient*. Tohoku J. Exp. Med., 2004, **203** (1), 9-16 —— In the past few decades, the number of bed-ridden elderly patients has been increasing. This group of patients is frequently fed with a liquid formula diet. The aim of this study was to evaluate the usefulness of a liquid formula diet containing dietary fiber (DF) for elderly bed-ridden patients. Eighteen elderly, bed-ridden patients were given L-3 Fiber®, a DF-containing liquid formula diet (DF-LFD), for 4 weeks, while a number of parameters were monitored, including serum levels of total cholesterol, triglyceride, total protein, creatinine, uric acid, glucose, sodium, potassium, and calcium, urine protein/sugar, and defecation frequency. Total protein, albumin and total cholesterol significantly increased following the administration of the DF-LFD, associated with an average increase in body weight of 1.94 kg (5.0%). Defecation frequency significantly increased one week after DF-LFD administration was started, but this effect was transient. Although a few patients complained of nausea, vomiting or abdominal pain, no severe side effects were seen. In conclusion, DF-LFD supplementation appears to be beneficial for elderly bed-ridden patients, and can increase nutritional-related parameters, such as body weight, total protein, albumin and total cholesterol, without severe side effects. ——— dietary fiber; cellulose; nutrition; liquid-formula diet; elderly bed-ridden patients

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A liquid formula diet (LFD) is used for patients who cannot take a meal orally or intravenously, and is more physiological than intravenous feeding. LFD has the additional advantage of being adaptable for home patients, as it does not require the high levels of sterility that are required for intravenous feeding. LFD can include natural foods and, a variety of nutrients, and is the most nutritionally appropriate dietary intake for elderly long-term bed-ridden patients.

In Japan and elsewhere world-wide, life expectancies have been increasing, leading to a steady increase in the so-called "graying population." This has in turn led to an expanding number of bed-ridden elderly patients, both in home-care and inpatient environments. Finding an appropriate diet for this growing elderly patient population has therefore become extremely important.

In the past, dietary fiber (DF) was referred to as unavailable carbohydrate, and was thought to be a burden on the digestive tract and an inhibitor of absorption and digestion of nutrients. However, Burkitt's fiber hypothesis (Burkitt 1971; Burkitt and Marshall 1972) during the 1970's provided stimulus for research in this area. Since that time, DF has attracted considerable attention for its beneficial physiological actions. These include improvement/maintenance of digestive tract function (Burkitt 1971; Burkitt et al. 1972; Munakata et al. 1995), inhibition of absorption of toxic substances (Burkitt 1971; Ershoff and Marshall 1975), improved glucose tolerance (Wolever et al. 1994), reduction of serum cholesterol (Keys et al.1960; Jenkins et al. 1980; Kris-Etherton et al. 2002) and the prevention of colorectal cancer (Burkitt 1971; Block et al. 1992) Furthermore, DF plays a role in ameliorating diarrhea (Zimmaro et al.1989). Thus, a DF-containing LFD (DF-LFD) was developed in the 1980s (Shinnick et al. 1989).

However, there is a possible major disadvantage associated with DF-LFDs: DF inhibits the absorption of nutrients, especially minerals (Ismail-Beigi et al. 1977; Slavin and Marlett1980), with even potentially fatal results in elderly bed-ridden patients, particularly those with an underlying pathological condition. This aspect must therefore be taken into very careful consideration.

To date, although there are a few studies which have comprehensively examined the effects of the administration of DF-LFD on the nutritional status, defecation frequency, blood – and other physiological parameters in human subjects (Ismail-Beigi et al. 1977; Slavin and Marlett1980; Lampe et al. 1991; Rahman et al. 2003), no studies have examined such effects of a DF-LFD on bed-ridden elderly subjects. The elderly, especially bed-ridden patients, are prone to have an imbalanced nutritive intake leading to a tendency towards malnutrition, creating a vicious circle by further exacerbating any underlying pathology or disease. A properly balanced food intake is necessary to maintain the nutritional state of this growing patient population. The use of DF-LFDs has become more common recently, therefore a study is required to examine the benefits or otherwise of feeding elderly bed-ridden patients with a DF-LFD.

This study was therefore designed to examine the effects of a DF-LFD (an LFD containing powdered crystal cellulose) on elderly bed-ridden patients, monitoring their body weight, defecation frequency, blood parameters and urine parameters to evaluate the effects of the DF-LFD.

Subjects and Methods

Subjects

Seventeen elderly patients (eight men and nine women) who were hospitalized in West Odate Hospital (Odate City, Akita Prefecture, Northern Japan) were enrolled in this study. The age of these patients ranged from 62 to 85 years with a mean of 74.8 years (Table 1).

Patients in this study were afflicted with a variety of underlying conditions; these included cerebral infarction (13 cases), cerebral hemorrhage (4 cases) and 1 case of Alzheimer's dementia (Table 1).

Written informed consent was obtained from

TABLE 1. *Subjects and their basic diseases*

	Age	Basic disease	Combination disease
Male	85	Cerebral infarction	Sick Sinus Syndrome
	63	Cerebral infarction	Chronic hepatitis
	62	Cerebral hemorrhage	Hypertension
	79	Cerebral infarction	Atrial fiblillation
	62	Cerebral hemorrhage	
	79	Cerebral hemorrhage	
	84	Cerebral infarction	
	77	Cerebral infarction	Atrial fiblillation
Female	67	Alzheimer's dementia	Urinary infection
	78	Cerebral infarction	Depression
	78	Cerebral infarction	
	81	Cerebral infarction	
	74	Cerebral infarction	
	78	Cerebral infarction	
	77	Cerebral infarction	Hypertension
	83	Cerebral hemorrhage	Atrial fiblillation
	69	Cerebral infarction	Chronic hepatitis
	70	Cerebral infarction	

each subject/subject's family before participation. The study was approved by the Ethics Committee of Hirosaki University School of Medicine.

Methods

Liquid-formula diet. L-3 Fiber® (Asahi Kasei Corporation, Tokyo) was used as the DF-LFD, which contains 2.4 g crystal cellulose per 200 ml (Table 2).

L-2 (Asahi Kasei Corporation, Tokyo), an LFD which does not contain DF, was administered to all subjects as a comparative autocontrol before L-3 Fiber® administration was commenced. The nutritional contents of both these diets are shown in Table 2.

Method of supplementation. Of the 18 patients participating in this study, 17 were tube-fed via the nose and one was tube-fed via a gastrostoma. The experimental schedule involved daily LFD administration for 2 weeks, followed by daily administration of DF-LFD for 4 weeks, 1200 kcal per day. The daily supplementary DF dose in the DF-LFD was 14.4 g per person, which is equivalent to the average daily DF intake in Japan (Nakaji et al., using the modified Prosky method) (2002).

Both the LFD and DF-LFD were administered three times per day at a rate of approximately 250-300 ml/hour.

Body weight, defecation frequency and stool appearance. The body weight, defecation frequency, stool appearance and any subjective symptoms were monitored daily in all subjects throughout the trial period. Before DF-LFD administration, three patients were severe constipation, who had a defecation per one week or more.

Blood and urine parameters. A number of blood and urine parameters were measured at two time points: one day before and three weeks after DF-LFD administration. Blood parameters included red blood cell (RBC) and white blood cell (WBC) counts, hemoglobin (Hb), platelet count, and hematocrit (Ht) in whole blood. The total protein (TP), albumin (Alb), glutamic oxaloacetic

TABLE 2. *Contents of L-2 and L-3 Fiber (per 200 ml)*

	L2		L3 Fiber	
Energy	203	(kcal)	200	(kcal)
Protein	8.0	(g)	8.0	(g)
Lipid	5.6	(g)	5.6	(g)
Carbohydrate	30.2	(g)	31.9	(g)
Salt	0.4	(g)	0.4	(g)
Water	169.5	(g)	167.4	(g)
Na	128	(mg)	157	(mg)
K	238	(mg)	250	(mg)
Ca	75	(mg)	75	(mg)
Mg	37	(mg)	38	(mg)
P	108	(mg)	100	(mg)
Fe	1.7	(mg)	2.4	(mg)
Cl	124	(mg)	170	(mg)
Cu	0.02	(mg)	0.01	(mg)
Zn	0.29	(mg)	0.35	(mg)
Mn	0.02	(mg)	0.01	(mg)
S	129	(mg)	100	(mg)
Vitamin A	365	(I.U.)	300	(I.U.)
Vitamin B_1	0.21	(mg)	0.25	(mg)
Vitamin B_2	0.39	(mg)	0.33	(mg)
Vitamin B_6	0.47	(mg)	0.50	(mg)
Vitamin B_{12}	0.30	(μg)	1.25	(μg)
Vitamin C	17.0	(mg)	25.0	(mg)
Vitamin D_3	30	(I.U.)	25	(I.U.)
Vitamin E	3.6	(mg)	3.0	(mg)
Niacin	5.7	(mg)	4.0	(mg)
Pantotic acid	1.1	(mg)	1.5	(mg)
Folic acid	56	(μg)	50	(μg)

transaminase (GOT), glutamic pyruvic transaminase (GPT), lactate dehydrogenase (LDH), γ glutamic transpeptitase (γ GTP), alkaline phosphatase (ALP), loicinaminopeptidase (LAP), total bilirubin (T-Bil), blood nitrogen urea (BUN), creatinine (Creat) and uric acid (UA) levels were monitored. Additionally, total cholesterol (T-Cho), HDL-cholesterol (HDL-Cho), triglyceride (TG), free fatty acid (FFA), phospholipid, glucose, sodium (Na), potassium (K), calcium (Ca), chloride (Cl) and phosphate (P) levels in serum were also monitored. Analysis of urine samples included parameters such as glucose and protein, which were checked four times during this study. The atherogenic Index (AI) was additionally calculated by the following equation:

$$\mathrm{AI} = \frac{(\mathrm{T{-}Cho}){-}(\mathrm{HDL{-}Cho})}{(\mathrm{HDL{-}Cho})}$$

Statistical analysis

The difference in values/frequencies of parameters were tested using the χ^2 test or paired *t*-test. A probability (p) of < 0.05 was considered as significant.

Results

Blood parameters

Significant increases in TP, Alb and T-Cho were seen in patients after DF-LFD administration (p<0.05 in each). However, there was no change in either HDL-Cho and AI.

There were no major changes in electrolytes or liver function. Although one patient exhibited a temporary impairment of liver and kidney function and a temporary electrolyte imbalance, these changes spontaneously improved without any need for intervention (Table 3).

Urine analysis

There were no significant changes in the urine samples during the course of this study (Table 4).

Body weight

After two weeks of DF-LFD administration, the patients' body weight was found to have increased by an average of 0.69 kg (no significant difference from the value immediately before DF-LFD administration). After four weeks of treatment with the DF-LFD, the patients' body weight had increased by an average of 1.94 kg (5%), which was significant (p<0.05) when compared with the value before DF-LFD administration.

Of the 18 patients given the DF-LFD, 14 showed an increase in body weight, seven of whom showed increases of over 5% with 1-5% seen in the remaining 7. Of the other 4 patients, one showed no change and three experienced weight losses ranging from 1% to 5% of their body mass.

Table 3. *Laboratory data*

Item	Unit	Normal range	One day before L-3 Fiber® diet	3 weeks after L-3 Fiber® diet
RBC	($10^4/\mu$l)	430-570	393.1±49.8	406.3±57.6
WBC	(/μl)	3300-9000	7291±2250	7620±1811
Hb	(g/100 ml)	13.5-17.5	12.1±1.4	12.5±1.6
Ht	(%)	39.7-52.4	35.9±4.3	36.5±4.7
TP	(g/100 ml)	6.5-8.2	6.2±0.6	6.5±0.6*
Alb	(g/100 ml)	3.8-5.0	3.33±0.41	3.55±0.41*
GOT	(U)	9-40	26.4±11.5	27.0±18.0
GPT	(U)	5-35	22.4±14.0	23.8±22.1
LDH	(U)	110-230	316.5±77.6	319.2±99.5
T-Bil	(mg/100 ml)	0.2-1.2	0.4±0.1	0.4±0.2
BUN	(mg/100 ml)	7-20	16.3±4.2	18.1±5.5
Creat	(mg/100 ml)	0.7-1.2	0.7±0.2	0.7±0.2
UA	(mg/100 ml)	3.8-8.0	4.1±1.4	4.2±1.5
T-Cho	(mg/100 ml)	130-250	181.5±32.1	193.2±39.0*
HDL-Cho	(mg/100 ml)	30-70	48.5±10.2	51.0±15.2
TG	(mg/100 ml)	30-149	111.1±42.1	113.9±51.0
Glucose	(mg/100 ml)	70-109	104.5±24.0	105.0±21.4
Na	(mEq/liter)	138-149	135.6±3.6	135.0±4.6
K	(mEq/liter)	3.5-5.0	3.9±0.4	3.8±0.5
Cl	(mEq/liter)	99-110	97.5±3.6	96.8±4.9
Atherogenic Index	—		2.7±0.9	2.8±0.9

Significant difference from pre-administration. *p<0.05.

TABLE 4. *Urinary data*

		Pre	Three weeks after
Protein	–	11	13
	±	1	0
	+	4	1
	2+	2	3
	3+	0	1
Glucose	–	16	17
	±	2	0
	+	0	0
	2+	0	1
	3+	0	0

Defecation frequency and stool appearance

Administration of the DF-LFD initially resulted in a significantly increased frequency of defecation and fecal output when compared with those observed during LFD administration ($p<0.05$); however, the frequency subsequently decreased. There was a tendency (not statistically significant) towards an increased proportion of watery stools during the first 2 weeks of DF-LFD administration (Fig. 1).

One patient showed a change from watery stools to formed stools after DF-LFD administration. However, the overall defecation state (e.g., chronic constipation) did not change in any other patients after DF-LFD administration. One patient had diarrhea after starting DF-LFD administration, but recovered during the course of this study.

Subjective symptoms

Three patients complained of abdominal distension immediately after starting DF-LFD administration, but this improved after two or three days of observation. Although a few patients complained of such effects as nausea, vomiting and abdominal pain, there were no severe side effects. No loss of feeding tube patency was experienced during the course of this study.

DISCUSSION

The source of DF in the DF-LFD used in this study was crystal cellulose, which is a water-insoluble fiber known to increase stool volume and shorten transit time within the large intestine. In the current study, the DF-LFD significantly increased defecation frequency without causing diarrhea. Therefore, a DF-containing formula diet might be useful for maintaining or improving large intestinal function. While this was a significant finding, it was also true that the DF-LFD could not improve chronic constipation. The

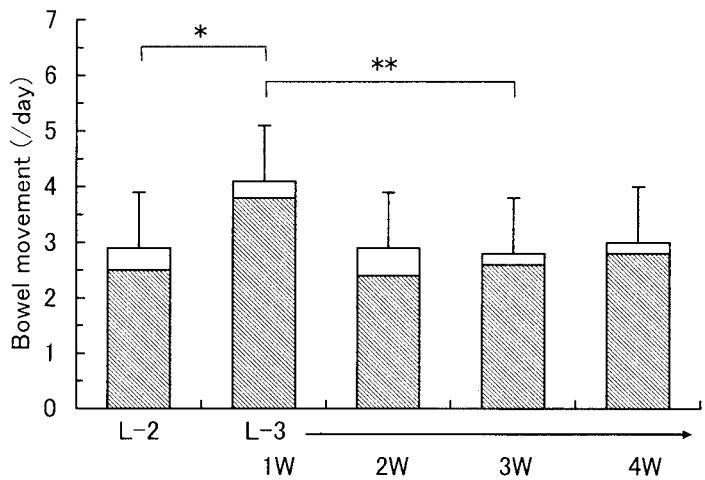

Fig. 1. Changes in defecation frequency and stool appearance. ▨, formed stool; □, watery stool. Different in defecation frequency from one week after DF-LFD administration. $^{*}p<0.05$, $^{**}p<0.01$.

reason for this may be explained by the fact that the constipation of elderly, bed-ridden patients is a result of marked relaxation of the large intestine, i.e., physiological rather than pathological.

One of the main purposes behind adding DF to LFD is to prevent diarrhea due to administration of the latter. In the current study, there was only one case who had watery stools after LFD administration, but who showed a change from watery stools to formed stools after DF-LFD administration.

The inhibition of the absorption of nutrients (especially minerals) by DF administration (Ismail-Beigi 1977; Slavin 1980) demands much attention, because elderly patients easily become nutritionally insufficient. It should be noted, however, that this study showed a increase in nutritional parameters such as TP, Alb, and T-Cho associated with L-3 Fiber® administration. On the other hand, one patient showed a drop in the plasma potassium level during the administration period, but this change spontaneously improved without any need for intervention. Therefore, we can say that, in general, the administration of DF-LFD improved the nutritional status of the subjects.

The very elderly are extremely prone to taking a nutritionally insufficient diet, which can easily lead to cardiopulmonary/kidney dysfunction and electrolytic imbalance with dehydration (Eisenberg 2002). In the current study, there was one case of transient liver dysfunction, but it is not clear whether this was associated with the enteral feeding.

This study has two limitations. Firstly, the stool weight was not assessed, so we cannot examine the relationship between DF-LFD administration fecal output in detail. Secondly, four weeks of L-3 Fiber® administration might be insufficient to evaluate definitively its effects.

Despite these limitations, this study demonstrates that a DF-LFD is useful to furnish nutrients for bed-ridden elderly patients, and indicates that DF-LFD administration can be applied for home medical/health care. However, long-term observation of these patients is required in further multicenter studies with larger patient populations, and perhaps LFDs with different types and amounts of DF, to elucidate completely both the beneficial effects and the side effects of DF-LFDs.

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