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A Possibility that a Deficiency in Dietary Fiber Causes Depression

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Abstract

The aim of the present study was to clarify whether a deficiency in dietary fiber intake causes depression by analyzing behavior of mice in the forced swim test (FST). The FST is widely used to evaluate the activity of antidepressant drugs. In the test, immobility of mice is considered as depression-like behavior. Mice were divided into two groups: experimental group and control group. A cellulose deficient diet that contained no cellulose was given to the mice of the experimental group, and a diet that contains 5.0% cellulose was given to the mice of the control group. After 3 or 4 weeks, immobility times of the mice in the experimental group were significantly longer than those in the control groups. On the other hand, there were no significant differences in body weights between the mice in the two groups. Based on these results, it is speculated that a deficiency in dietary fiber intake causes depression by factors other than obesity.

Keywords: depression, dietary fiber, cellulose, forced swim test

1.0 Introduction

Depression is a mental health disorder that is highly prevalent in the general population (Bountziouka, Polychronopoulos, Zeimbekis, Papavenetiou, Ladoukaki, Papairakleous, Gotsis, Metallinos, Lionis, & Panagiotakos, 2009). Takeida et al. have reported a relationship between depression and mortalities from cancer, pneumonia, and suicide in the elderly (Takeida, Nishi, & Miyake, 1997). Additionally, it has been reported that the economic burden of depression in Japan was approximately $11 billion, and $1,570 million out of that was related to direct medical costs (Okumura & Higuchi, 2011). Therefore, it is important to take preventive measures.

Depression has been reported to be associated with ingested foods. Previous studies have suggested that fish intake is negatively associated with depression (Bountziouka et al., 2009; Tanskanen, Hibbeln, Tuomilehto, Uutela, Haukkala, Viinamäki, Lehtonen, & Vartiainen, 2001; Hibbeln, 1998). In addition, other studies have suggested that fruits and vegetables intake also negatively correlates with depression. In Canada, greater fruit and vegetable intake was significantly correlated with lower incidences of depression (McMartin, Jacka, & Colman, 2013). Among female university students in European countries, depressive symptoms were associated with less frequent consumption of fruits and vegetables (Mikolajczyk, El Ansari, & Maxwell, 2009). Fruits and vegetables are high in fiber, although the foods contain more than just fiber (Slavin, 2013). Fang et al. found that higher levels of depressive symptoms were associated with lower dietary fiber intake (Fang, Egleston, Gabriel, Stevens, Kwiterovich, Snetselaar, Longacre, & Dorgan, 2013). In their study, depressive symptoms had no significant effect on dietary fiber intake in an adjusted analysis. It is unclear whether a deficiency in dietary fiber intake causes depression.

The aim of the present study was to clarify whether a deficiency in the dietary fiber intake causes depression. In order to achieve this aim, a diet deficient in cellulose was given to mice, and the forced swim test (FST) was performed.

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Dietary fiber includes cellulose, hemicelluloses, pectin, and lignin (Slavin, 2013). Since most diet for mice contain only cellulose among those dietary fibers, the influence of a deficiency in cellulose was investigated in this study. The FST was adopted to evaluate the depression-like behavior of the mice in this study, since the test is widely used to evaluate the activity of antidepressant drugs (Kurtuncu, Luca, Dimitrijevic, Uz, & Manev, 2005).

2.0 Materials and Methods

2.1. Animals

C57BL/6J male mice were used in this study. The mice were purchased from CLEA Japan, Inc. (Japan). The mice were housed under conditions of 12 hr light/dark cycle (lights on at 8:00 A.M.) with access to food and water *ad libitum*. The procedures used in this study were approved by the Animal Research Ethics Committee, Hirosaki University Graduate School of Medicine.

2.2. Diets

The diet lacking cellulose, and AIN-93M, which contains 5.0% cellulose, were used. Both of these diets were purchased from Oriental Yeast Co., Ltd. (Japan).

2.3. An outline of experimental plan

The mice (10-11 weeks old) were divided into two groups: experimental group and control group. The diet deficient in cellulose was fed to the experimental group, and the AIN-93M was fed to the control group. After 2, 3, and 4 weeks, body weights of the mice were measured, and FST was carried out. These experiments were conducted three times.

2.4. FST

FST was carried out as previously described (Liu, Jia, Gou, Sun, Fu, Lan, Li, & Yin, 2013; El Yacoubi, Bouali, Popa, Naudon, Leroux-Nicollet, Hamon, Costentin, Adrien, & Vaugeois, 2003) with a slight modification. Mice were placed individually into a vertical acrylic cylinder (25 cm high; 10 cm in diameter) filled with 10-cm-deep water (21-22°C). After the 6-min period of the test, they were removed and allowed to dry. The time spent immobile was measured for the last 4-min period. Immobility of the mice in the test was considered as depression-like behavior (Kurtuncu et al., 2005). Immobility was defined as keeping still, making only minimal movements to keep the head above water, or only using righting movements to remain afloat.

2.5. Statistical analysis

Kolmogorov-Smirnov test was first performed to clarify whether immobility times and body weights per group at each experimental time conformed to the normal distribution. At each experimental time, if the continuous variables in both groups conformed to the normal distribution, the variables were presented as mean values ± standard deviation, and probability (*P*) value was calculated by *t* test. On the other hand, if the continuous variables in either group did not conform to the normal distribution, the variables were presented as median, minimum and maximum, and *P*- value was calculated by Mann-Whitney test. All of the reported *P* values were based on two-tail tests and *P* values of <0.05 were considered significant. The Japanese version of Microsoft Excel 2007 for Windows (Microsoft Japan Co., Ltd., Japan) and Ekuseru-Toukei 2012 (Social Survey Research Information Co., Ltd., Japan) were used for all of the statistical calculations.

3.0 Results

3.1. Body weight

At all experiment times, there were no significant differences in body weights between the experimental group and the control group (Tables 1, 2).

Table 1: Body weight per group (grams, mean ± SD)

		Control group (n=12)	Experimental group (n=12)	*P*-value [a]
Experiment 1st	2 weeks	25.8±1.9	26.7±1.6	0.26
	3 weeks	26.6±1.8	27.7±1.9	0.13
	4 weeks	— [b]	— [b]	— [c]
Experiment 2nd	2 weeks	27.3±1.9	26.3±1.6	0.19
	3 weeks	27.9±1.9	27.1±1.6	0.29
	4 weeks	28.7±1.8	27.7±1.8	0.18
Experiment 3rd	2 weeks	25.8±1.5	26.1±1.0	0.49
	3 weeks	27.1±1.5	26.9±1.1	0.75
	4 weeks	27.4±1.1	27.4±1.1	0.97

[a] The *t* test was used to determine *P*-values.
[b] Mean values were not calculated since the values in either of the groups did not conform to the normal distribution.
[c] The *t* test was not used since the values in either of the groups did not conform to the normal distribution.

Table 2: Body weight per group (grams)

			Control group (n=12)	Experimental group (n=12)	*P*-value [a]
Experiment 1st	4 weeks	Median	26.4	28.3	
		Minimum	25.4	25.6	0.073
		Maximum	31.5	31.8	

[a] The Mann-Whitney test was used to determine *P*-values.

3.2. Forced swim test

As shown in Tables 3 and 4, at 2 weeks, there were no significant differences in the immobility times between the experimental group and the control group. At 3 weeks in the 2nd and 3rd experiment, immobility times of the experimental group were significantly longer than those of the control group. On the other hand, in the 1st experiment, at 4 weeks after beginning to provide the diets, the immobility times of the experimental group were significantly longer than those of the control group while there was no significant difference between the two groups at 3 weeks.

Table 3: Immobility time per group (seconds, mean ± SD)

		Control group (n=12)	Experimental group (n=12)	*P*-value [a]
Experiment 1st	2 weeks	114.0±37.8	129.7±39.8	0.33
	3 weeks	119.2±42.4	143.0±52.4	0.23
	4 weeks	104.2±75.5	161.1±40.1	0.031
Experiment 2nd	2 weeks	127.0±39.7	122.9±31.5	0.78
	3 weeks	147.5±37.8	178.9±26.9	0.028
	4 weeks	— [b]	— [b]	— [c]
Experiment 3rd	2 weeks	— [b]	— [b]	— [c]
	3 weeks	147.8±29.6	175.9±30.5	0.032
	4 weeks	140.3±66.2	171.9±31.4	0.15

[a] The *t* test was used to determine *P*-values.
[b] Mean values were not calculated since the values in either of the groups did not conform to the normal distribution.
[c] The *t* test was not used since the values in either of the groups did not conform to the normal distribution.

Table 4: Immobility time per group (seconds)

			Control group (n=12)	Experimental group (n=12)	*P*-value [a]
Experiment 2nd	4 weeks	Median	211.7	216.2	0.53
		Minimum	89.7	159.2	
		Maximum	235.5	232.9	
Experiment 3rd	2 weeks	Median	128.5	149.2	0.065
		Minimum	46.7	90.0	
		Maximum	162.7	165.4	

[a] The Mann-Whitney test was used to determine *P*-values.

4.0 Discussion

Dietary fiber has various functions. It has been reported that intake of dietary fiber increases fecal weight (Cummings, Hill, Jivraj, Houston, Branch, & Jenkins, 1979; Stasse-Wolthuis, Albers, van Jeveren, Wil de Jong, Hautvast, Hermus, Katan, Brydon, & Eastwood, 1980), increases frequency of stools (Stasse-Wolthuis et al., 1980), and also shortens intestinal transit time (Cummings et al., 1979; Stasse-Wolthuis et al., 1980). In addition, it has been reported that dietary fiber intake is inversely associated with fasting blood insulin levels (Byrd-Williams, Strother, Kelly, & Huang, 2009) and reduces insulin response to a high carbohydrate meal (Potter, Coffman, Reid, Krall, Albrink, 1981). On the other hand, it has been shown that dietary fiber intake decreases plasma low-density lipoprotein cholesterol in men with mild hypercholesterolemia (Tinker, Schneeman, Davis, Gallaher, & Waggoner, 1991).

It has also been suggested that intake of dietary fiber is negatively associated with depression (Fang et al., 2013). However, there have been few reports indicating that a lower intake of dietary fiber causes depression. The present study investigated whether a deficiency in dietary fiber intake cause depression, by analyzing the immobile behavior of mice in FST which is considered as depression-like behavior. Immobility times of the mice given a diet deficient in cellulose for 3 or 4 weeks were significantly longer than those of the mice in the control group.

Fiber intake is known to be inversely associated with weight gain (Bes-Rastrollo, Martínez-González, Sánchez-Villegas, de la Fuente Arrillaga, & Martínez, 2006). Furthermore, significant positive correlations between obesity and depression have been found by meta-analysis (Abou Abbas, Salameh, Nasser, Nasser, & Godin, 2015). Based on the previous studies, it could be speculated that a deficiency in fiber intake causes depression via obesity. However, in the present study, there were no significant differences in body weight between the experimental group and the control group. Therefore, a deficiency in dietary fiber intake may cause depression by factors other than obesity, such as increase of fecal weight, control of fasting blood insulin levels, or a reduced insulin response.

5.0 Conclusion

The aim of the present study was to determine whether a deficiency in dietary fiber intake causes depression by analyzing behavior of mice in FST. A diet deficient in cellulose was given to the mice in the experimental group, and a diet containing 5.0% cellulose was given to the mice in the control group. At 3 or 4 weeks, immobility times of the mice in the experimental groups were significantly longer than those in the control groups. On the other hand, there were no significant differences in body weight between two groups. Based on these results, it is speculated that a deficiency in dietary fiber intake causes depression by factors other than obesity.

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