Original Article

Formulas providing adequate pantothenic acid, vitamin D, manganese, iron and vitamin A for infants fed with mother's milk (aged 6–11 months) according to the Japanese Dietary Reference Intakes prepared by the Ministry of Health, Labour and Welfare (2005 edition)

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Abstract

Weaning formulas served in hospitals and care facilities in Japan should conform to dietary reference intakes (DRIs). We examined whether the DRI for breastfed infants aged 6–11 months can be satisfied in dietary practice, with a particular focus on the fulfilment rates for vitamins, minerals, trace elements and electrolytes in weaning formulas containing energy and protein at levels either greater than or equal to the DRIs, as well as on the dietary profiles of weaning formulas to achieve the DRI for every nutrient. The results showed that no weaning formulas examined in this study fulfilled the DRI for pantothenic acid (5 mg), vitamin D (4 µg), manganese (1.2 mg) or iron (5.5 mg). Furthermore, their vitamin A content exceeded the DRI (350 µg RE). The discrepancy between the guidelines and actual dietary practice is probably because of the fact that the estimated reference values poorly reflect the actual dietary intake in the target population; for example, the pantothenic acid and manganese DRIs for breastfed infants aged 6–11 months were set based on the breast milk intake of younger infants (0–5 months) in combination with the breast milk contents. Our results suggest that dietary guidance for infants should include information to promote proper intakes of vitamins A and D, and iron by reducing the amount of vitamin A-rich foods and utilizing dietary vitamin D and iron supplements including government-approved specified health foods.

Keywords: dietary reference intakes, breastfeeding (6–11 months after birth), pantothenic acid, manganese, vitamin A, Japanese.

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Introduction

The Japanese dietary reference intakes (DRI, 2005 edition), comprising estimated energy requirements (EERs) and adequate intake (AI) of nutrients, were developed by the Ministry of Health, Labour and Welfare as basic guidelines to be used in dietary settings, including nutrition education and meal preparation in hospitals and care facilities (Notification No. 1228001 2004).

The AI of nutrients (except those of vitamin D and iron) for breastfed infants aged 6–11 months was extrapolated from the breast milk intakes of 0–5-month infants and the nutritional contents of breast milk in Japanese women, or estimated based on available data regarding breast milk and weaning meal intakes collected mainly in Canada and the USA in combination with the breast milk nutritional contents in Japanese women (the AI for potassium and sodium was calculated from the weaning food intake in

Japanese infants). The AI for vitamin D was calculated based on the dietary and circulating levels of vitamin D determined in Chinese infants, and for iron, the estimated average requirement and recommended intake were extrapolated from the values determined overseas through a factorial method (Ministry of Health, Labour and Welfare of Japan 2005). However, the recent National Health and Nutrition Survey in Japan lacks data concerning infants aged 6–11 months (Ministry of Health, Labour and Welfare of Japan 2008), and their actual nutritional intakes have not been investigated.

When the pantothenic acid and manganese contents in mother's milk are compared between Japan and Canada (Health Canada 1999; Ministry of Education, Culture, Sports, Science and Technology 2006), the pantothenic acid content of mother's milk was about two times higher in Japan than in Canada, but its DRI is about three times higher in Japan. The manganese content of mother's milk was comparable, but its DRI is higher in Japan than in Canada.

The Recommendations for Conducting Weaning in the guidebook for supporting feeding and weaning prepared by the Maternal and Child Health Division (2007), Equal Employment/Children and Families Bureau, Ministry of Health, Labour and Welfare, describes how weaning should be carried out, cooking methods and approximate amounts of foods per meal. According to the government-sponsored scientific committee for the development of the Guidelines for Supporting Feeding and Weaning, nutritional information on weaning formulas given at nutrition counselling sessions or provided in parenting magazines was based on the Recommendations for Conducting

Weaning (Ministry of Health, Labour and Welfare of Japan 2006). From these considerations, we explored weaning formulas for breastfed infants aged 6–11 months that satisfy the DRI of vitamins, minerals, trace elements and electrolytes as well as the recommended nutrient intakes described in the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007).

Methods

Nutritional contents and type of weaning formulas

Nutrient contents

In this study, we selected the DRI for 6–11-month females as the target dietary intake to evaluate energy value and nutrient content of weaning formulas; although DRIs of nutrients are equal for both genders (except for iron DRI), the energy DRI is set lower for females than for males, requiring stricter formula planning for females.

The target levels included the EER, recommended daily allowance for iron (no iron AI established) and AIs for other nutrients. The percentage of the content of each nutrient relative to its target levels was regarded as the fulfilment rate (FR). Iodine and selenium, which are not included in the Standard Tables of Food Composition in Japan, were excluded from this study.

Type of weaning formula

The type of weaning formula for infants aged 7–8 and 9–11 months in the Recommendations for Conduct-

Key messages

- In terms of the DRIs for breastfed infants aged 6–11 months, none of the weaning meals examined fulfilled the AIs of nutrients.
- Compared with the AI, hospital formulas were likely to contain excessive vitamin A, but insufficient pantothenic acid, vitamin D, manganese and iron levels.
- In practice, it was not possible to prepare a weaning meal with all the DRI requirements for infants aged 6–11 months.
- The discrepancy between the guidelines and actual dietary practice suggests a need to improve the nutritional standards for infants.
- When implementing the current DRI in weaning infants, particular attention should be paid to excessive vitamin A intake and the reduced consumption of pantothenic acid, vitamin D, manganese and iron.

Table 1. Amount of foods provided in the sample meals relative to that proposed in the Recommendations for Conducting Weaning and daily values of food items for infants aged 7–8 months and 9–11 months

		Hospital formula	Modified hospital formula*	Conformity formula†
7–8 months				
I	Grains‡	220.0 ± 0.0%	100.0 ± 0.0%	87.0 ± 9.5%
II	Vegetables, fruits‡	333.5 ± 34.2%	102.7 ± 2.0%	204.9 ± 28.8%
III	Fish‡	54.7 ± 48.9%	22.5 ± 27.5%	28.2 ± 33.9%
	Meat‡	67.5 ± 42.7%	22.5 ± 27.5%	9.8 ± 13.2%
	Tofu‡	1.2 ± 2.4%	20.0 ± 25.1%	12.8 ± 25.9%
	Eggs‡	Whole egg	Yolk of 1 egg	0.6 ± 2.6%
		29.9 ± 40.9%	14.0 ± 14.9%	
	Dairy products‡	0.3 ± 0.9%	23.2 ± 25.0%	3.3 ± 10.8%
	Total‡	153.6%	102.0%	54.7%
Cooking oils§		0.9 ± 0.5 g	0.1 ± 0.2 g	0.3 ± 0.5 g
				Sesame seeds 8.4 ± 0.4 g
Sugar§		0.7 ± 0.7 g	4.2 ± 2.0 g	6.5 ± 2.7 g
Number of food items§		13.2 ± 0.7	13.2 ± 0.7	16.1 ± 0.5
Volume of nursing milk§		900 ± 0 mL	751 ± 27 mL	654 ± 22 mL
9–11 months				
I	Grains‡	100.0 ± 0.0%	73.8 ± 0.0%	48.9 ± 1.9%
II	Vegetables, fruits‡	157.2 ± 40.1%	100.3 ± 3.3%	105.5 ± 13.7%
III	Fish‡	29.5 ± 45.6%	19.1 ± 34.8%	14.6 ± 24.1%
	Meat‡	54.0 ± 46.1%	20.9 ± 32.0%	2.6 ± 6.0%
	Tofu‡	12.4 ± 24.1%	20.4 ± 32.0%	10.0 ± 21.1%
	Eggs‡	18.2 ± 35.6%	18.3 ± 35.8%	14.4 ± 27.6%
	Dairy products‡	0.7 ± 3.1%	21.6 ± 36.3%	13.4 ± 23.1%
	Total‡	114.8%	100.3%	55.0%
Cooking oils§		1.3 ± 0.9 g	8.2 ± 2.6 g	5.9 ± 1.2 g
				Sesame seeds 5.0 ± 2.4 g
Sugar§		1.5 ± 0.7 g	1.4 ± 1.0 g	6.8 ± 2.6 g
Number of food items§		20.5 ± 0.1	19.4 ± 0.8	18.7 ± 0.6
Volume of nursing milk§		850 ± 0 mL	283 ± 12 mL	425 ± 33 mL

Value are expressed as mean ± standard error day⁻¹. *Formula based on the Recommendations for Conducting Weaning. †Formula designed to maximally follow the dietary reference intake for every nutrient. ‡Should be 100% when the formula meets the Recommendations for Conducting Weaning; Maternal and Child Health Division (2007). §Mean amount per day for 10 days.

ing Weaning was applied to the DRI for infants aged 6–11 months. According to the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007), the weaning formula was served twice daily for infants aged 7–8 months and thrice daily for those aged 9–11 months.

Formulas and methods for the preparation of meals

The nutritional contents were calculated according to the 5th Supplemented Edition of the Standard Tables of Food Composition in Japan (Ministry of Education, Culture, Sports, Science and Technology 2006) (Table 1).

Hospital formula

The hospital formulas are weaning meals for breast-fed infants aged 6–11 months with higher energy and protein contents than the DRI by assuming that parts of the meals are left unconsumed.

Concerning the weaning meals provided at the Department of Pediatrics, a certain University Hospital, during a 10-day period, the volume of milk prepared by dissolving compounded powder milk at the instructed concentration (nursing milk) and meals were investigated, and nutritional contents [mean ± standard error (SE)] were calculated by replacing nursing milk with mother's milk.

Formula based on the Recommendations for Conducting Weaning

The hospital formula was modified to meet the DRI for energy and protein by reducing grains (food group I), vegetables/fruits (II) and protein foods (III) to conform to the recommended nutrient intakes described in the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007).

The modifications were made with attention to evenly distribute protein foods, i.e. fish, meat, tofu, eggs and dairy products, over 10 days. The number of food items used per day was equalized to that in the hospital formula. Mother's milk was prepared in the amount calculated by subtracting the energy of infants aged 7–8 or 9–11 months in the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007) from the EER of the DRI for infants aged 6–11 months.

Conformity formula

Weaning meals were designed to maximally reflect the DRI for each nutrient while ignoring the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007).

Formulas with 100% DRI for pantothenic acid, vitamin D or iron

The types of formulas were prepared by modifying the conformity formula to satisfy the 100% DRIs for either pantothenic acid, vitamin D or iron (which were later found not to be fulfilled in the conformity formula), and the FR for other nutrients in the formulas was estimated as a percentage relative to the respective DRI (Table 2).

FR of food group, energy and nutrients

Mean energy and nutrient contents in the formulas (for infants of two age groups: 7–8 and 9–11 months) were calculated using 10 days' meals for each type of formula (with or without mother's milk), and the FR for energy or a nutrient was estimated as a percentage of the mean value relative to the target value (Table 3).

Food group analyses were conducted based on the recommended food group intakes provided in the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007). For each formula, mean food group contents in a meal averaged over 10 days' meals were compared with the recommended per-meal values of overall food group intakes (for foods in groups I and II) or individual food item intakes (for fish, meat, tofu, eggs and dairy products in food group III), and expressed as a percentage relative to the corresponding recommended value (regarded as 100%; for group III foods, the sum of the recommended percentage intakes of the five items was regarded as 100%). For oil, sugar and milk contents, average daily amounts calculated from the 10 days' meals were used for the comparison (Table 1).

Food group-based analyses of nutrient contents

To obtain a basis to select food for DRI-based meal planning, we calculated Spearman's rank correlation coefficients among the vitamin B1 and B6, pantothenic acid, vitamin D, manganese and iron contents (vertical axis), and energy, protein and vitamin A contents (horizontal axis) for fish, meats and vegetables (processed foods are excluded) using the Standard Tables of Food Composition in Japan (Ministry of Education, Culture, Sports, Science and Technology 2006) (Table 4).

Results

Hospital formula

Mother's milk and food consumption

The average ($\pm$ SE) amounts of mother's milk calculated for infants aged 7–8 and 9–11 months were 900 ± 0 and 850 ± 0 mL day⁻¹, respectively (Table 1).

Food group analysis revealed greater amounts of grains (food group I), vegetables/fruits (II) and protein foods (III) in the meals for 7–8-month infants, with small amounts of group I foods in those for 9–11-month infants, compared with the recommended food intake for the respective age groups

Table 2. Development of conformity formula for infants aged 7–8 months and 9–11 months

Nutrition quantity		Conformity formula*		Nutrient	FR (%)	Nutrient	FR (%)	Nutrient	FR (%)
		Nutrient	FR (%)						
7–8 months Increased				Pantothenic acid	100.0	Vitamin D	100.0	Iron	100.0
				Fat	102.8	Fat	104.1	Protein	124.7
				Fat energy ratio	110.5	Fat energy ratio	104.0	Fat	110.7
				Vitamin A	259.7	Vitamin A	161.7	Fat energy ratio	110.3
Reduced		Pantothenic acid	84.6	Energy	93.2	Protein	96.7	Vitamin B2	92.5
		Vitamin D	97.5	Vitamin B6	93.3	Vitamin B2	97.5	Niacin	93.3
		Iron	76.4	Vitamin B12	80.0	Vitamin B6	96.7	Vitamin B6	83.3
				Vitamin D	50.0	Pantothenic acid	82.6	Pantothenic acid	79.4
9–11 months Increased				Manganese	87.5	Phosphorus	95.4	Vitamin D	50.0
				Iron	36.4	Iron	94.5	Manganese	84.2
				Pantothenic acid	100.0	Vitamin D	100.5	Iron	101.8
				Vitamin A	487.7	Fat	105.9	Protein	103.3
						Fat energy ratio	105.0	Fat	102.1
						Vitamin A	206.6	Fat energy ratio	103.0
Reduced		Pantothenic acid	74.6	Energy	97.2	Protein	89.3	Vitamin B2	95.0
		Vitamin D	67.5	Vitamin D	35.0	Vitamin B2	97.5	Pantothenic acid	72.0
		Iron	45.5	Iron	38.2	Pantothenic acid	79.0	Vitamin D	35.0
						Calcium	88.4		
						Iron	38.2		

FR, fulfillment rate; DRI, dietary reference intake. The types of formulas were prepared by modifying the conformity formula to satisfy the 100% DRIs for either pantothenic acid, vitamin D or iron (which were later found not to be fulfilled in the conformity formula), and the FR for other nutrients in the formulas was estimated as a percentage relative to the respective DRI. *Formula designed to maximally follow the DRI for every nutrient.

Table 3. Mean energy and nutrient content of the sample formulas consisting of foods and mother's milk (%)

	Target value	Hospital formula [§]		Modified hospital formula ^{*§}		Conformity formula ^{†§}	
		7–8 months	9–11 months	7–8 months	9–11 months	7–8 months	9–11 months
Energy	650 kcal	139.1 (49.1)	158.5 (73.4)	100.0 (24.9)	100.0 (71.7)	100.0 (35.1)	100.0 (57.5)
Protein	15 g	141.3 (75.3)	178.0 (115.3)	100.7 (45.3)	100.7 (80.0)	101.3 (53.3)	100.7 (69.4)
Lipids	29 g	129.7 (21.0)	136.2 (33.4)	100.3 (9.7)	99.7 (65.5)	100.3 (21.4)	100.0 (48.6)
Fat/energy ratio	40%	93.5	86.3	100.5	100.3	100.5	100.5
Vitamin B1	0.30 mg	83.3 (53.3)	110.0 (80.0)	56.7 (30.0)	56.7 (46.7)	123.3 (100.0)	126.7 (113.4)
Vitamin B2	0.40 mg	112.5 (45.0)	127.5 (65.0)	87.5 (30.0)	65.0 (45.0)	100.0 (50.0)	100.0 (113.4)
Niacin	3.0 mg	133.3 (60.0)	193.3 (56.7)	96.7 (50.0)	70.0 (20.0)	460.0 (43.3)	183.3 (30.0)
Vitamin B6	0.30 mg	93.3 (93.3)	136.7 (136.7)	50.0 (50.0)	70.0 (70.0)	120.0 (120.0)	153.3 (153.3)
Folic acid	60 µg	150.0 (150.0)	210.0 (210.0)	66.7 (66.7)	115.0 (115.0)	126.7 (126.7)	185.0 (185.0)
Vitamin B12	0.5 µg	160.0 (160.0)	220.0 (220.0)	80.0 (80.0)	120.0 (120.0)	220.0 (220.0)	120.0 (120.0)
Pantothenic acid	5.00 mg	116.4 (90.0)	49.6 (28.4)	92.2 (75.2)	123.0 (85.0)	84.6 (65.4)	74.6 (42.6)
Vitamin C	40.00 mg	195.0 (112.5)	222.5 (107.5)	135.0 (95.0)	100.0 (35.0)	152.5 (82.5)	170.0 (52.5)
Vitamin A	350 µg RE	231.4 (118.3)	260.0 (148.3)	136.3 (98.6)	147.7 (37.1)	147.1 (61.1)	144.3 (88.3)
Vitamin E	3 mg	163.3 (120.0)	176.7 (63.3)	126.7 (100.0)	136.7 (36.7)	130.0 (43.3)	146.7 (90.0)
Vitamin D	4.0 µg	92.5 (25.0)	92.5 (27.5)	80.0 (22.5)	32.5 (12.5)	97.5 (47.5)	67.5 (35.0)
Vitamin K	7 µg	942.9 (814.3)	1357.1 (1228.5)	514.3 (400.0)	828.6 (785.7)	1042.9 (942.9)	1228.6 (1171.5)
Magnesium	32 mg	212.5 (128.1)	278.1 (196.9)	143.8 (71.9)	156.3 (131.3)	462.5 (400.0)	359.4 (318.8)
Calcium	250 mg	127.2 (30.0)	137.6 (45.6)	106.0 (24.8)	80.0 (49.6)	122.0 (51.2)	100.0 (54.0)
Phosphorus	280 mg	148.9 (57.1)	130.0 (87.5)	82.1 (44.6)	88.9 (74.6)	107.9 (75.0)	125.0 (103.6)
Manganese	1.20 mg	72.5 (72.5)	97.5 (97.5)	24.2 (24.2)	61.7 (61.7)	110.0 (110.0)	117.5 (117.5)
Iron	5.5 mg	30.9 (23.6)	43.6 (38.2)	16.4 (10.9)	23.6 (21.8)	76.4 (70.9)	45.5 (41.9)
Copper	0.30 mg	156.7 (66.7)	190.0 (103.3)	116.7 (40.0)	113.3 (86.6)	166.7 (100.0)	153.3 (110.0)
Zinc	3.0 mg	140.0 (50.0)	170.7 (83.7)	106.7 (30.0)	96.7 (70.0)	110.0 (43.3)	100.0 (56.7)
Potassium	800 mg	124.5 (70.5)	151.0 (100.0)	78.5 (33.5)	73.3 (56.3)	118.4 (79.1)	109.4 (83.9)

*Formula based on the Recommendations for Conducting Weaning. †Formula designed to maximally follow the dietary reference intake for every nutrient. §All values except those under the column 'Target value' indicate percentage value compared with 'Target value'. The number in parentheses shows percentage of the supply from mother's milk in each formula.

shown in the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007).

Nutrient contents

The contents of vitamin D, manganese and iron in the hospital formulas for 7–8- and 9–11-month infants were below the DRI, along with lower FR for vitamins B1 and B6 in the formulas for 7–8-month infants. In the formulas for both age groups, however, the FR for energy, protein, and vitamins A and K exceeded 100%, and the vitamin A content was higher than the tolerable upper limit (UL). Additionally, the FR for folic acid, vitamins B12 and C, and magnesium was more than 200% in the formulas for infants aged 9–11 months. The fat/energy ratios of the formulas for both age groups were below the target levels, but their lipid contents were higher than the AI (Table 3).

Modified hospital formula

Mother's milk and food consumption

The average ($\pm$ SE) amounts of mother's milk for infants aged 7–8 and 9–11 months were 751 ± 27 and 283 ± 12 mL day⁻¹, respectively (Table 1).

Food group analysis showed that the formulas for both age groups contained sufficient amounts of foods from each food group to meet the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007), except for the group I foods (grains) in the menus for 9–11-month infants.

Nutrient contents

The formulas for the two age groups did not fulfil the DRIs for vitamins B1 and B2, niacin, vitamin B6, pantothenic acid, vitamin D, phosphorus, manganese,

Table 4. Spearman's rank correlation coefficients between vitamin B1 and B6, pantothenic acid, vitamin D, manganese and iron contents, and energy, protein and vitamin A contents

	Energy	Protein	Vitamin A
Fish			
Vitamin B1	0.299*	0.263*	0.152
Vitamin B6	0.260*	0.719*	-0.209**
Pantothenic acid	0.308*	0.061	0.248*
Vitamin D	0.444*	0.229*	0.034
Manganese	-0.109	-0.140	0.091
Iron	0.321*	0.043	0.181**
Meat			
Vitamin B1	-0.327*	0.456*	-0.145
Vitamin B6	-0.553*	0.783*	-0.209*
Pantothenic acid	-0.530*	0.467*	-0.091
Vitamin D	0.127	-0.102	0.557*
Manganese	-0.188**	0.144	-0.011
Iron	0.255*	0.698*	-0.176
Vegetable			
Vitamin B1	0.528*	0.807*	0.405*
Vitamin B6	0.520*	0.591*	0.374*
Pantothenic acid	0.489*	0.664*	0.287*
Vitamin D	–	–	–
Manganese	0.155	0.422*	0.333*
Iron	0.255*	0.698*	0.594*

* $P < 0.01$; ** $P < 0.05$.

iron and potassium, with FR of less than 60% for vitamins B1 and B6, manganese and iron in the menus for 7–8-month infants, as well as for vitamin B1, pantothenic acid, vitamin D and iron in the formulas for 9–11-month infants. Furthermore, the folic acid and vitamin B12 contents in the formulas for 7–8-month-olds and the calcium and zinc contents in those for 9–11-month infants were below the DRIs. The vitamin A content was higher than the DRI (Table 3).

Conformity formula

Mother's milk and food combinations

The average ($\pm$ SE) amounts of mother's milk for infants aged 7–8 and 9–11 months were 654 ± 22 and 425 ± 33 mL day⁻¹, respectively (Table 1).

The numbers of food items (except for cooking oils, sugar and other seasonings) used in the formulas for 7–8- and 9–11-month infants were 16.1 ± 0.5 and 18.7 ± 0.6 , respectively. Food group analysis demonstrated that the conformity formulas for both age

groups consisted mainly of foods from the group II, with smaller amounts of group I and III foods, when compared with the recommended food intake for the age groups described in the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007). These findings suggested a need to incorporate other types of foods into the meals, such as seaweed (sea lettuce, green laver, dried laver and *hijiki*) and sesame seeds, rich sources of pantothenic acid, manganese and iron (requiring 5.5 ± 0.4 g of dried seaweed and 8.4 ± 0.4 g of sesame seeds to fulfil the DRI for 7–8-month infants, which was found to be impractical for infants of this age).

Nutrient contents

The pantothenic acid, vitamin D and iron contents in the formulas for both age groups were less than the DRI for age, with a particularly lower FR for iron in the menus for 9–11-month infants. The FR for vitamins A and K, and magnesium exceeded 100% (Table 3).

Formulas with 100% DRI for pantothenic acid, vitamin D or iron

Formula with 100% pantothenic acid DRI

When increasing the FR for pantothenic acid to 100% in the conformity formulas, the meals could no longer fulfil the DRI for energy, vitamin D and iron for both age groups as well as for vitamins B6 and B12, and manganese for 7–8-month-olds. The meals contained an excessive amount of vitamin A (above the UL).

Formula with 100% vitamin D DRI

Fulfilment of the vitamin D DRI led to a reduced content of protein, vitamin B2, pantothenic acid and iron in the meals for both age groups. The meals also contained insufficient (less than the DRI) amounts of vitamin B6 and phosphorus for 7–8-month infants, and calcium for those aged 9–11 months. The FR for lipids and vitamin A was higher than 100% for both age groups, and the vitamin A content in the menus for 9–11-month infants exceeded the UL.

Formula with 100% iron DRI

The meals containing the DRI level of iron did not satisfy the DRI for vitamin B2, pantothenic acid and vitamin D for both age groups, as well as the niacin, vitamin B6 and manganese DRI for 7–8-month infants. The protein, lipid and vitamin A contents were more than the DRI, with a vitamin A content exceeding the UL (Table 2).

Food group-based analyses of nutrient profiles

Fish

For fish, significant positive correlations were observed between vitamin B1 and B6, pantothenic acid, vitamin D and iron contents, and the energy content ($P < 0.01$ each); between vitamin B1, B6 and D contents, and the protein content ($P < 0.01$ each); and between pantothenic acid and iron contents, and the vitamin A content ($P < 0.01$, $P < 0.01$ and $P < 0.05$, respectively). There was a negative correlation between vitamin B6 and A contents ($P < 0.01$).

Meat

For meat, negative correlations were noted between vitamin B1 and B6, pantothenic acid and manganese contents, and energy content ($P < 0.01$ each, except manganese: $P < 0.05$), and between vitamin B6 and iron contents, and vitamin A content ($P < 0.01$ and $P < 0.05$, respectively).

Vegetables

For vegetables, also, significant positive correlations were observed between the vitamin B1 and B6, pantothenic acid and iron contents, and energy, protein and vitamin A contents ($P < 0.01$ each), and between manganese content, and protein and vitamin A contents ($P < 0.01$ each) (Table 4).

Discussion

Evaluation of the formulas

The average amounts of mother's milk incorporated into the hospital formulas (for 7–8- and 9–11-month

infants) and modified hospital formulas (for 7–8-month infants) were more than the estimated values from the national survey on dietary intake in Japanese infants (approximately 680 and 520 mL in infants aged 7 and 9 months, respectively; Nakano *et al.* 2003) or those from the survey regarding energy and protein intakes during the first post-natal year in Californian infants (646 mL in 9-month infants; Heing *et al.* 1993). The average amounts of mother's milk calculated for the modified hospital and conformity formulas (both for 9–11-month infants) were less than the survey results.

Hospital formulas are weaning meals for breastfed infants aged 6–11 months with higher energy and protein contents than the DRI by assuming that parts of the meals are left unconsumed. The contents of energy, protein and vitamin A were excessive for both infants aged 7–8 and 9–11 months, but the vitamin D, manganese and iron contents (for both age groups), and vitamin B1 and B6 contents (for infants aged 7–8 months), were below the target level. Given that the hospital formulas were served along with a substantial amount of mother's milk and that pantothenic acid is richly present in mother's milk, overall pantothenic acid supply was considered to be adequate (Table 3).

In the modified hospital formula, the contents of vitamins B1 and B2, niacin, vitamin B6, pantothenic acid, vitamin D, phosphorus, manganese, iron and potassium did not fulfil the DRI for both infants aged 7–8 and 9–11 months, and the vitamin A content was excessive. Concerning the contents of vitamins B1, B6 and D, manganese, and iron, which were below the DRI in the hospital formula, the FR was 60% or less in either formulas for infants aged 7–8 or 9–11 months, or both. The pantothenic acid content was sufficient in the hospital formula, but not in the modified hospital formula, with the FR of less than 60% in the menus for 9–11-month infants. The modified hospital formula for 7–8-month infants contained insufficient amounts of folic acid and vitamin B12, while the formula for those aged 9–11 months did not meet the DRI for calcium and zinc. The FR of vitamin B2, niacin, pantothenic acid, vitamin D, calcium, copper, zinc and potassium was lower in the formula for infants aged 9–11 months than in that for 7–8 months

because, for these nutrients, a relatively smaller proportion was provided from mother's milk in the formula for 9–11 months [percentage of a nutrient derived from mother's milk in the total supply of the nutrient (milk-derived/total ratio) for the formulas for infants aged 7–8 and 9–11 months: vitamin B2, 57.5 vs. 20.0%; vitamin D, 57.5 vs. 20.0%; calcium, 81.2 vs. 30.4%; copper, 76.7 vs. 26.7%; zinc 76.7 vs. 26.7%; and potassium, 45.0 vs. 17.0%; respectively]. Similarly, the FR of vitamin B6, folic acid, vitamin B12 and manganese was lower in the formula for 7–8 month-olds than in that for 9–11-month-olds because of a relatively smaller percentage of the weaning food-derived/total ratio for these nutrients (Table 3).

In the conformity formula, the weaning meals consisted mainly of vegetables, seaweed and sesame seeds, which are rich sources of pantothenic acid, manganese and iron; however, the formula did not fulfil the DRI for pantothenic acid, vitamin D and iron.

Formulas with 100% DRI for pantothenic acid, vitamin D or iron

The conformity formulas prepared in the present study can be modified further to fulfil the individual DRI for pantothenic acid, vitamin D or iron, but not to satisfy the DRI of the three nutrients in a balanced manner (Table 2). In the formulas satisfying the DRI for pantothenic acid, vitamin D or iron, the FR for protein, lipids and vitamin A exceeded 100%, with a vitamin A content of more than the UL.

Food group-based analyses of nutrient profiles

As described in the Results, selection of foods rich in vitamins B1 and B6, pantothenic acid, vitamin D, manganese and iron can lead to an excessive intake of energy, protein and vitamin A. For fish, a negative correlation was observed between vitamin B6 and A contents, and vitamin B6 was positively correlated with energy and protein, so that the selection of foods from this group that are rich in vitamin B6 also results in excess in energy and protein. For meat, negative correlations were noted between vitamin B1 and B6, pantothenic acid and manganese contents, and energy and vitamin A contents. However, as meat has a high

protein content, formulas with a large amount of meat result in excess in protein. Also, meat becomes dominant in (III) protein foods (Table 4).

Thus, the preparation of formulas that fulfil DRI for breastfed infants aged 6–11 months, i.e. those with a pantothenic acid content of 5 mg, vitamin D content of 4 µg, manganese content of 1.2 mg and iron content of 5.5 mg; protein content of 15 g; and vitamin A content of 350 µg RE; is considered to require contradictory selection of foods. Therefore, formulas that fulfil both the DRI for infants aged 6–11 months and the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007) are impossible to prepare. Formulas are inevitably deficient in pantothenic acid, vitamin D, manganese and iron, and excessive in vitamin A. Vitamin B1 and B6 requirements are also difficult to meet.

International comparison of DRI

Table 5 shows DRI of vitamins B1 and B6, pantothenic acid, vitamin D, manganese and iron abroad (Ministry of Health, Labour and Welfare of Japan 1999; Republic of Korea 1999; Food and Nutrition Research Institute 2002; United States Department of Agriculture 2002; Food and Nutrition Board, Institute of Medicine, National Academies 2004; World Health Organization and Food and Agriculture Organization of the United Nations 2004; Health Canada 2005; Ministry of Health, Labour and Welfare of Japan 2005). The Japanese DRIs of pantothenic acid and manganese are higher, those of vitamin D and iron are lower, and those of vitamins B1 and B6 are similar, compared with international levels, partly because many Japanese foods have higher pantothenic acid and manganese contents and lower vitamin D and iron contents than foreign foods.

However, there are no marked differences in the results of food analyses between Japan and Canada concerning pantothenic acid, vitamin D, manganese and iron (Health Canada 1999; Ministry of Education, Culture, Sports, Science and Technology 2006). Moreover, Spearman's rank correlation coefficients of the results of food analyses concerning vegetables between Japan and Canada (Tsutie *et al.* unpublished data) were $r = 0.680$ ($P < 0.01$) for pantothenic acid,

Table 5. Recommended nutrient intakes in Japan and other countries (a) and nutritional contents of various formulas (b)

(a) Country	Month	Vitamin B1 (mg)	Vitamin B6 (mg)	Pantothenic acid (mg)	Vitamin D (μ g)	Manganese (mg)	Iron (mg)	Year
Japan	6–11	0.3	0.3	5	4	1.2	4 (estimated mean)	2005
WHO	7–12	0.3	0.3	1.8	5	–	5.5 (recommended amount)	2004
							6.2 (15%)	
							7.7 (12%)	
							9.3 (10%)	
							18.6 (5%)	
DRI	7–12	0.3	0.3	1.8	5	0.6	11	2004
USA	6–12	0.4	0.6	3	10	0.6–1.0	10	2002
Canada	7–12	0.3	0.3	1.8	5	0.6	11	2005
United Kingdom	7–9	0.2	0.3	1.7	7	16 μ g	7.8	1991
	10–12	0.3	0.4					
Germany	4–12	0.4	0.6	3	10	0.6–1.0	8	1991
Philippines	6–12	0.4	0.3	–	5	0.6	10	2002
Australia	7–12	0.35	0.45	–	–	–	9.0	1991
South Korea	5–10	0.4	0.5	–	10	–	10	1995
Vietnam	0–1 (year)	0.3–0.4	–	–	–	–	10–11	1996
Indonesia	0–1 (year)	0.3–0.4	–	–	–	–	3–5	1994
Singapore	0–1 (year)	0.28–0.38	–	–	–	–	7	1988
Thailand	0–1 (year)	0.3–0.5	–	–	–	–	6–8	1989
(b) Formula								
Hospital formula	7–8	0.25	0.28	5.82	3.7	0.87	1.7	
Modified hospital formula*	7–8	0.17	0.15	4.60	3.2	0.29	0.9	
Conformity formula†	7–8	0.36	0.36	4.23	3.9	1.32	4.2	
Hospital formula	9–11	0.33	0.41	6.15	3.6	1.17	2.4	
Modified hospital formula*	9–11	0.16	0.21	2.47	1.4	0.74	1.3	
Conformity formula†	9–11	0.38	0.46	3.73	2.7	1.41	2.4	

WHO, World Health Organization; DRI, dietary reference intake. *Formula based on the Recommendations for Conducting Weaning. †Formula designed to maximally follow the DRI for every nutrient.

$r = 0.720$ ($P < 0.01$) for manganese and $r = 0.729$ ($P < 0.01$) for iron, showing positive correlations. Vitamin D was excluded from the statistical analysis because its reference value in the Standard Tables of Food Composition in Japan is zero. These results suggest that there are no marked differences in their contents in foods between the two countries. Therefore, the Japanese DRIs are considered to be set at high levels concerning pantothenic acid and manganese. Pantothenic acid and manganese are not included in the DRI in some countries. As shown in Table 5, the pantothenic acid and manganese DRI provided in the foreign dietary guidelines can be fulfilled by the modified hospital formula prepared in the present study (except for manganese DRI for 7–8-month infants).

Concerning vitamins B1 and B6, wheat bread enriched with vitamin B1 (Tasnim *et al.* 2005) and cereals with high vitamin B1 and B6 contents (Health Canada 1999) are available in Canada. Similarly, vitamin B-fortified rice is sold in Japan. In weaning meals, the DRI for vitamins B1 and B6 can be fulfilled by using these food items.

Breast milk from Canadian women was shown to contain a lower amount of vitamin D compared with that of Japanese, and the Canadian DRI for vitamin D was higher than the Japanese value. The Canadian Society of Pediatrics reported that rickets because of vitamin D deficiency in children had been common until about 3 years before (1985), but that it was rare at the time (1988) primarily because of the intake of vitamin D-enriched milk and vitamin tablets (Indian and Inuit Health Committee, Canadian Paediatric Society 1998). For iron intake, the Canadian DRI is higher than that in Japan, although the breast milk iron contents are comparable between the two populations. The Canadian Society of Nutritionists suggests that iron deficiency anaemia is related to the period of breastfeeding and that measures such as the consumption of special iron-enriched compound milk are necessary (Innis *et al.* 1997). The Canadian DRIs for vitamin D and iron, which are higher than those in Japan, are likely to be achieved by taking advantage of these dietary supplements.

These results suggest that nutrition counselling for infants should include more information on AIs of

vitamin D, iron and vitamin A so as to promote the intake of dietary vitamin D and iron supplements, such as government-approved specified health foods, and the reduced consumption of vitamin A-rich foods.

In health and nutritional surveys of Japanese until 2005 (Ministry of Health, Labour and Welfare of Japan 2008), infants aged 6–11 months were not included. There have also been few studies on diet of infants aged 6–11 months, and those that were reported were conducted before the publication of the 5th Edition of the Standard Tables of Food Composition of Japan or DRIs (Nishimura & Endo 1984; Okuma *et al.* 1990; Nakano *et al.* 1995; Suzuki *et al.* 2004).

The Japanese DRIs of pantothenic acid and manganese for infants aged 6–11 months, which were calculated from the breast milk intakes of infants aged 0–5 months in combination with the breast milk contents in Japanese women (Ministry of Health, Labour and Welfare of Japan 2005), are not considered to reflect the actual nutritional intake of Japanese. We hope that AIs better matching the above nutritional intake are adopted in the next revision of the DRI.

Conclusion

Meeting the DRI concerning vitamins, minerals, trace elements and electrolytes for infants aged 6–11 months required contradictory selection of foods, and it was impossible to prepare formula that simultaneously fulfilled (1) 5 mg pantothenic acid, (2) 4 µg vitamin D, (3) 1.2 mg manganese, (4) 5.5 mg iron and (5) 350 µg RE vitamin A in the DRI and the Recommendations for Conducting Weaning (Maternal and Child Health Division 2007). In such formula, pantothenic acid, vitamin D, manganese and iron were deficient, and vitamin A exceeded the UL. In dietary guidance, warnings should be given about deficiencies of vitamin D and iron, which require vitamin D and iron supplementation, and excess vitamin A. Furthermore, the current DRIs for pantothenic acid and manganese for 6–11-month infants need to be revised.

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Conflicts of interest

No conflicts of interest have been declared.

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