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The nutritional status of vegetarian Buddhist nuns compared to omnivorous women in South Korea

By

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Ernährungsstatus vegetarischer buddhistischer Nonnen verglichen mit omnivoren Frauen in Südkorea

eingereicht von

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"*A vegetarian diet will make your body and soul free*"

(Buddhist Master, Jeong-O)

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1 Introduction

1.1 Definition of a vegetarian

In 1847, the Vegetarian Society of the United Kingdom first used the term vegetarian (Vegetarian Times 1996). The word is a combination of “vegetable” and the noun suffix “-arian” (= believer, advocate) (Merriam Webster 2010). Originally, the word “veget-“ comes from the Latin word vegetus (= lively, fresh) (Latin Dictionary and Grammar Aid 2005). Therefore, vegetarians can be defined as those who consume a diet exclusively or mostly based on foods of plant origin, such as grains, vegetables, fruits, legumes, nuts, and seeds. Depending on the type of vegetarian, foods produced from living animals, such as milk, eggs, and honey are included in their diet (Leitzmann and Keller 2010). This definition serves as a basis for the present study.

When defining a vegetarian diet, some authors suggest that the emphasis should be on whether vegetables, fruits, grains, and other plant foods are included in the diet and not on whether meat is merely excluded from it. Furthermore, a person who consumes only small amounts of fruits, vegetables, and whole grains, but high amounts of processed food should not be classified as a vegetarian in spite of the meatless diet (Johnston and Sabaté 2000). For instance, the so called “pudding-vegetarian” should not be regarded as a real vegetarian. The term “pudding-vegetarians” was coined by the natural philosopher Are Waerland. They do not eat meat and fish, but mainly consume highly processed foods containing high amounts of calories but little of noncaloric nutrients such as vitamins, minerals, and phytochemicals. This way, they may develop nutrient deficiencies and health problems (Leitzmann and Keller 2010).

1.2 Types of vegetarians

The dietary patterns of vegetarians are diverse and not homogenous. Therefore, it is not easy to categorize the type of vegetarian according to the term (Phillips 2005; Dwyer 2003; Weinsier 2000). In general, the types of vegetarians can be classified by their restrictions (Table 1). The first four types in Table 1 are the major and classical vegetarian types. The other types are based on a vegetarian diet.

Vegans or strict vegetarians eat a plant-only diet excluding all foods derived from animals. Some of them even avoid honey. Lacto-vegetarians allow milk products in their diets while ovo-vegetarians eat eggs instead. Lacto-ovo-vegetarian is the most frequent form; they consume both milk products and eggs (Craig and Mangels 2009).

A fruitarian is a kind of vegan who consumes mainly foods that do not kill the plant origin, i.e. fresh and dried fruits, nuts, seeds, and selected vegetables (Phillips 2005). A macrobiotic diet mainly consists of whole grains, beans, and locally grown vegetables. Soy food and sea vegetables are also included. Instead of red meat and poultry, white-meat fish and shellfish are eaten. Refined salt and sugars are substituted by sea salt, rice syrup, and barley malt (Kushi and Blauer 2004). Pesco-vegetarians eat fish and seafood, but no red meat and poultry. Milk products and eggs are not restricted (Phillips 2005). Pollo-vegetarians exclude red meat and fish in the diet, but eat chicken (Sabaté *et al*. 2001). Semi-vegetarians occasionally eat meat and fish (less than once a week), and mainly practice a vegetarian diet (Fraser 2009).

Table 1: The various types of vegetarians and their restrictions

	Red meat	Poultry	Fish	Milk	Egg	Other restriction
Vegan (strict V)	X	X	X	X	X	Honey (X)
Lacto-V	X	X	X	O	X	-
Ovo-V	X	X	X	X	O	-
Lacto-ovo-V	X	X	X	O	O	-
Fruitarian	X	X	X	X	X	Root & stem (X)
Macrobiotic V	X	X	Δ	Δ	X	Refined salt and sugar (X)
Pesco-V	X	X	O	O	O	
Pollo-V	X	O	X	O	O	
Semi-V	Δ	Δ	Δ	O	O	Red meat, poultry and fish dish less than once a week

V vegetarian; X excluded in the diet; O included or not restricted in the diet; Δ occasionally included or partly restricted in the diet

1.3 Motives for being a vegetarian

There are various reasons for being a vegetarian as shown in Table 2 (Kaza 2005; Phillips 2005; Leitzmann and Hahn 1996). These reasons are determined by one's own experiences, thoughts, concerns, and expectations (Leitzmann and Keller 2010) and have also changed over time (Weinsier 2000):

- in the 1940s and 1950s: religious beliefs,
- in the 1960s and 1970s: antiestablishment movement, political statement,
- since the 1980s: health reasons.

Nowadays, the main four motives are religious, ethical, health and ecological concerns. Most vegetarians do not only have only one steady motive but a combination of two or more (Leitzmann and Keller 2010; Dwyer 1991).

Table 2: Various motives for being a vegetarian

Health concerns	Ecological/ environmental reasons
Ethical reasons; animal welfare	Philosophical reasons; religious or spiritual beliefs
Political reasons	Sensory and taste preferences; aesthetic
Hygiene and toxicology	Social influences
Economic reasons	

1.4 Trend of vegetarian studies and changing paradigm

Scientific progress in nutrition research leads to an improvement in the knowledge about vegetarian nutrition. In early nutrition studies, the potential health risks of vegetarian diets were often overestimated (Sabaté 2001).

In the 1960s and 1970s nutrient deficiency diseases were more prevalent than nowadays. At that time, while performing nutrition research and policy, the most crucial issue was the nutrient adequacy meeting nutritional needs (Table 3). Nowadays a vegetarian diet is one of the most important dietary patterns that can prevent chronic degenerative diseases and promote health (Craig and Mangels 2009).

Table 3: Main themes of published articles about vegetarian nutrition in the biomedical literature, 1966-1995 (Sabaté *et al*. 1999)

	1966-1975		1976-1985		1986-1995		Total	
	n	(%)	n	(%)	N	(%)	n	(%)
Main themes								
Nutritional adequacy issues	14	(48.2)	66	(37.2)	82	(24.2)	162	(29.7)
Preventive and therapeutic application	7	(24.1)	68	(38.5)	135	(40.0)	210	(38.6)
Multiple themes	0	(0)	10	(5.6)	30	(8.9)	40	(7.4)
Guidelines and recommendations	2	(6.9)	12	(6.8)	31	(9.2)	45	(8.3)
Other	6	(20.7)	21	(11.9)	60	(17.8)	87	(16)
Total	29	(100)	177	(100)	338	(100)	544	(100)

In Figures 1-3 the three models developed by Sabaté illustrate health risks and benefits of populations consuming either a diet mainly based on plant foods or on animal foods (Sabaté 2001):

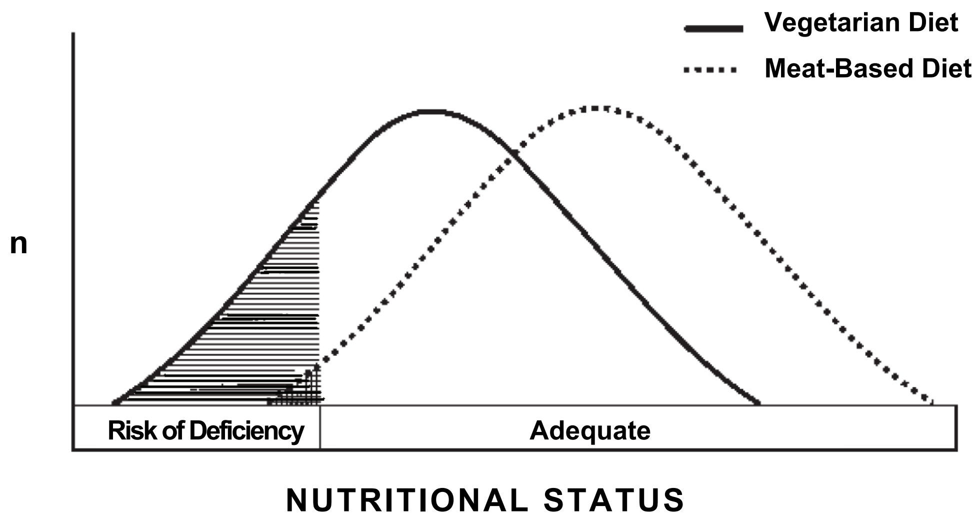

Figure 1: Early model on the adequacy of a vegetarian diet compared to a meat-based diet (Sebaté 2001)

The early model in the 1960s, as shown in Figure 1, visualizes a high potential risk of nutrient deficiency in vegetarianism. In comparison, the meat-based diet depicts a mostly adequate nutritional status with low risk of deficiency. This one-sided model did not consider potential detrimental effects caused by excessive intake of food from animal origins. However, dietary intake and health status have no linear relationship. Moreover, all types of diets include both potential health risks and benefits.

In Figure 2, the current model prevailing since the 1970s illustrates the public health risks and benefits of a vegetarian and a meat-based diet. In contrast to the early model, both ends of the extremes have a risk of deficiency and excess. In this model, there is no overall difference in the risk-to-benefit ratio between the two dietary patterns. Besides, this model concludes that the health status will not be improved if the curve shifts to the right or left by changing consumption of animal or plant foods. When moving the curve, the increased area on one side would be equal to the decreased area on the other side.

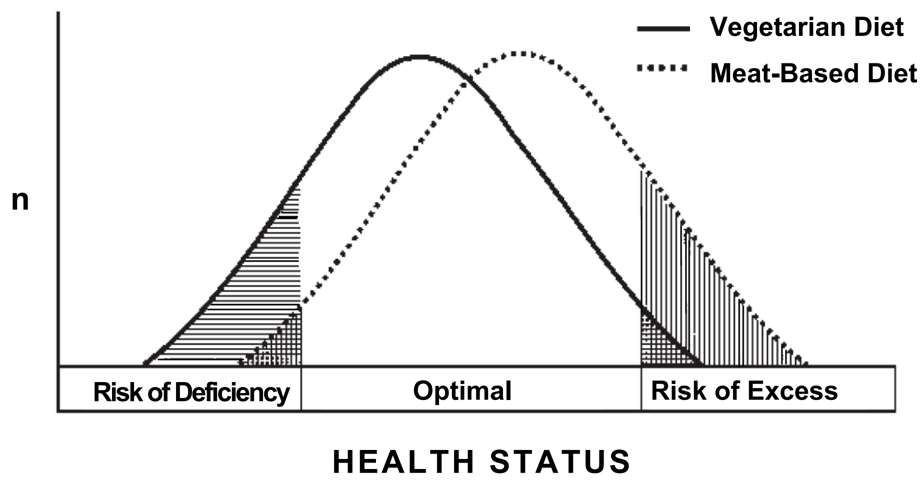

Figure 2: Current model on the public health risks and benefits of vegetarian and meat-based diets (Sabaté 2001)

For instance, if small amounts of dairy products or eggs are substituted by small amounts of vegetables in a vegan diet, the risk of the vitamin B_{12} deficiency will be reduced. At the same time, the risk for coronary disease increases. In fact, this slightly increased risk is outweighed by the considerable risk reduction of vitamin B_{12} deficiency. Therefore, the risk-benefit ratio of a vegetarian diet is lower than that of a meat-based diet. Conversely, if small amounts of vegetables are substituted by small amounts of meat in the animal food-based diet, the benefit of this exchange is actually small. To reduce the risk-to-benefit ratio, substantial changes in this diet pattern are needed.

Since the 1990s, the focus of vegetarian studies has shifted from potential health risks of eating meat to benefits of practicing a vegetarian diet (Willett 1999). The food components which only exist in foods of plant origin, such as dietary fiber, antioxidants, and phytochemicals have been investigated extensively as well as their protective effects on diseases (Miller *et al*. 2002; Owen *et al*. 2000; Craig and Beck 1999).

In Figure 3 the proposed model presents the new understanding of the role of vegetarian and meat-based diets in health and disease in affluent societies. In this model, the area under the meat-based diet curve that presents the risk of deficiency is wider than in previous models. The shape of the curves now differs between the two diets as well as the risk-to-benefit ratio.

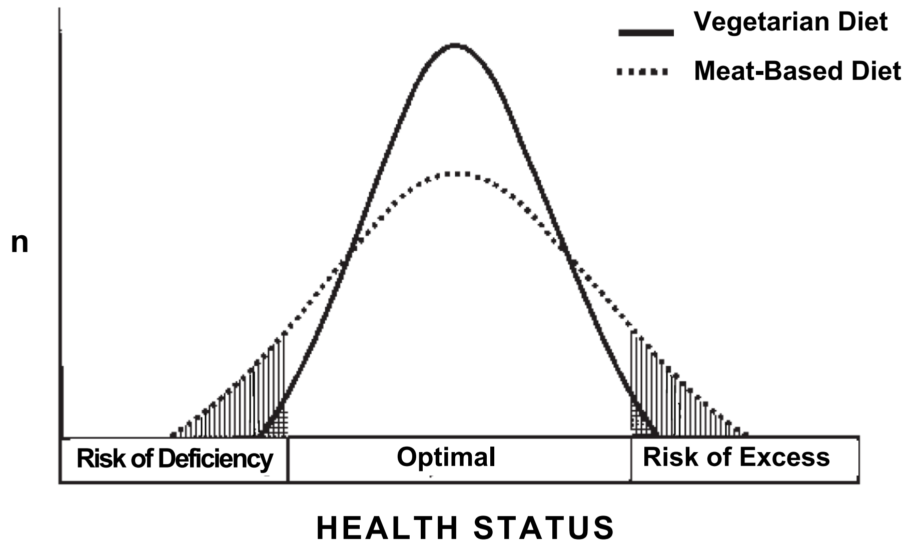

Figure 3: Proposed model on the public health risks and benefits of vegetarian and meat-based diets (Sabaté 2001)

Populations consuming diets mainly based on animal foods have higher risks of chronic degenerative diseases than populations consuming diets mainly based on plant foods. This may not only be caused by an excessive intake of energy, cholesterol, and saturated fatty acids but also by a lack of food components found only in plant foods such as phytochemicals. Phytochemicals are bioactive non-nutrient compounds in fruits, vegetables, grains, and other plant foods that have been linked to reducing the risk of major chronic diseases (Okarter and Liu 2010; Pierini *et al*. 2008; Thomasset *et al*. 2007).

1.5 The number of vegetarians worldwide

There are no accurate statistics on the number of vegetarians worldwide. The estimated data often differ between the surveys or vegetarian organizations. The data are sometimes collected from a small sample size and are not representative for the whole population. Furthermore, the actual number of vegetarians may be less than estimated because some self-defined vegetarians do eat meat (Haddad and Tanzman 2003; Barr and Chapman 2002).

Table 4 shows the estimated number of vegetarians in the world 2007 by various vegetarian organizations (Leitzmann and Keller 2010).

Table 4: The number of vegetarians in the world 2007 (Sources: Estimation of various vegetarian organization) (Leitzmann and Keller 2010)

Countries	Population (Mio)	Number of vegetarians (in 1000)	Percentage of vegetarian in the population (%)
Australia	20.4	610	3
Austria	8.1	245	3
Belgium	10.2	205	2
Canada	32.9	1,300	4
Croatia	4.5	165	4
Czech Republic	10.2	155	2
Denmark	5.4	80	2
France	64.4	1.230	2
Germany	82.3	6,600	8
Great Britain	60.2	5,400	9
India	1,129.9	452,000	40
Ireland	4.1	245	6
Israel	7.2	600	8
Italy	59.1	5,900	10
Netherlands	16,3	700	4
Norway	4.6	90	2
Poland	38,1	380	1
Rumania	21.6	865	4
Spain	45.2	1,800	4
Sweden	9.2	270	3
Switzerland	7.6	230	3
USA	303.3	12,130	4

India has the most and USA the second most number of vegetarians in the world. In Europe, Germany has the highest number of vegetarians while Italy has the highest proportion of vegetarians in the population.

Current official statistics on Korean vegetarians are not available, but the Korean Vegetarian Union has estimated that vegetarians account for less than 1% of the population with increasing interest in vegetarianism (Hyun Hyun, 2008).

1.6 Effects of a vegetarian diet on health

Well-planned vegan and vegetarian diets can not only provide all nutrients at all stages of the life cycle, but also prevent chronic and degenerative diseases (Craig and Mangels 2009). However, to ensure the adequate supply of some critical nutrients, such as iodine and vitamin B_{12}, fortified foods or dietary supplements should be included into a vegan diet, if a sufficient supply of these nutrients from natural sources is not available due to food cultural and geographical reasons.

1.6.1 Beneficial effects

Obesity

Western vegetarians tend to have a lower BMI than omnivores and the prevalence of obesity in vegetarians is less frequent than in omnivores (Fraser 2009; Tonstad *et al*. 2009; Alewaeters *et al*. 2005; Davey *et al*. 2003). A vegetarian diet generally has a lower energy density, lower fat, lower protein, and higher fiber content compared to a meat-based diet (Spencer *et al*. 2003). Additionally, a healthy lifestyle, such as regular physical activity, low alcohol consumption, and non-smoking has a protective effect against obesity (Appleby *et al*. 1998).

Coronary heart disease (CHD) and ischemic heart disease (IHD)

Large cohort studies consistently have shown that mortality from CHD and IHD in vegetarians was much lower than in omnivores (Fraser 2009; Chang-Claude *et al*. 2005; Key *et al*. 1999). In contrast, the increased consumption of meat was positively associated with increasing mortality from IHD (Chang-Claude *et al*. 2005). Besides, risk factors for heart disease, such as high levels of blood cholesterol and high blood pressure, were reduced in vegetarians (Tonstad *et al*. 2009). The components of plant foods such as nuts (e.g. almonds), viscous fiber (e.g. from oat and barley), soy proteins, and phytosterols lower serum lipids and cardiovascular diseases (Sabaté 1999; Pietinen *et al*. 1996).

Cancer

There have been many cohort studies on cancer and vegetarian diets. Vegetarians in the EPIC-Oxford study had a lower incidence of overall, stomach, and lung cancer than omnivores (Key *et al*. 2009b). British vegetarians had a lower risk of stomach, ovarian, and bladder cancer than omnivores (Key *et al*. 2009a). German vegetarians had a lower mortality from colorectal cancer than omnivores (Chang-Claude *et al*. 2005). A cohort study with Seventh-Day-Adventists (SDA) in the USA showed that colon and prostate cancer in vegetarians were significantly less frequent than in omnivores (Fraser 1999).

Type 2 diabetes mellitus

The prevalence of type 2 diabetes mellitus in US-Adventist vegetarians was much lower than in omnivores. The components of plant foods can directly improve the status of diabetics or complications of diabetes, e.g. high level of blood cholesterol, cardiovascular disease, and renal disease (Fraser 2009). The low BMI of vegetarians also contributes to the decreasing risk of type 2 diabetes (Tonstad *et al*. 2009). Many studies showed that the consumption of whole grains or cereal fiber has protective effect on type 2 diabetes, whereas the consumption of refined grains increased the risk of type 2 diabetes (Okarter and Liu 2010).

1.6.2 Nutrient intake

Iron

Iron deficiency and iron deficiency anemia affect not only vegetarians but also omnivores. The iron content of a vegetarian diet is comparable to that of an omnivorous diet, however, iron in a vegetarian diet is generally less bioavailable than in an omnivorous diet (Hunt 2003). Heme iron occurs solely in animals, especially in blood and muscle tissue. Heme iron is highly bioavailable and its absorption is less affected by other dietary inhibitors (Hunt 2002). The bioavailability of nonheme iron varies strongly depending on diet composition and the status of the body iron stores (Cook 1990). The representative inhibitors of iron absorption are phytate and polyphenols which occur in substantial amounts only in plant food such as grains, legumes, vegetables and fruits. Additionally, milk proteins (casein and whey) and egg white were reported as inhibitors of iron absorption in humans (Hurrell and Egli 2010). Many studies showed that vegetarian women in childbearing age tend to have lower body iron stores and blood ferritin levels than omnivores (Hunt 2003).

Iodine

Like iron deficiency, iodine deficiency is one of the major global health problems. The iodine content of the soil in which plants are grown and with the kind of fodder the animals are raised has a crucial impact on the iodine content of food. Therefore, iodine intake depends on the geological location (iodine deficient area: Africa, Southeast and Central Asia, Europe) and the diet (Patrick 2008; ICCIDD *et al*. 2001).

Marine products contain substantial amounts of iodine. Dietary sources of iodine for vegetarians are iodized table salt, sea vegetables, bakery products using iodine containing dough stabilizer or iodized salt, and dairy products (Craig and Pinyan 2001). Conversely, some vegetables are known to be "goitrogenic foods", which reduce iodine bioavailability. The representative goitrogenic foods are cruciferous vegetables, millet, cassava, nuts, lima beans, sweet potatoes, and soy products (Gaitan 1990; Craig and Pinyan 2001). However, these natural goitrogens have little adverse effect on thyroid function of iodine-replete individuals (Messina and Redmond 2006).

Although omnivores have a more favorable iodine intake than vegetarians, there is no evidence that lacto-ovo-vegetarians have a higher risk of iodine deficiency than the general population. However, vegans who avoid iodized salt, sea vegetables and dietary iodine supplements have a high risk of deficiency (Remer *et al*. 1999; Craig and Pinyan 2001; Lightowler and Davies 2002).

Vitamin B_{12}

Vegetarians definitely have lower serum vitamin B_{12} levels than omnivores (Elmadfa and Singer 2009). Vitamin B_{12} is synthesized by microorganisms and is known to be predominantly present in animal tissue and generally absent in plants, with the exception of some seaweeds (Watanabe 2007; Yamada *et al*. 1996; Herbert 1988). Therefore, vitamin B_{12} is the most critical nutrient for vegetarians, especially vegans, if they do not use fortified food or dietary supplements. Fortunately, vitamin B_{12} is seldom exhausted due to enterohepatic circulation, and the clinical manifestation of vitamin B_{12} deficiency rarely occurs, even without intake of vitamin B_{12} for many years (Herbert 1988). Moreover, a lack of vitamin B_{12}-dependent methionine synthase, which demethylates methyl tetrahydrofolate (THF), can lead to folate functional deficiency (Selhub *et al*. 2009). Because vitamin B_{12} and folate are metabolically interrelated, the symptoms of apparent deficiency in these vitamins are often identical and indistinguishable (Green 2008). One typical manifestation of these nutrients deficiencies is a macrocytic anemia due to immature erythrocytes resulting from defective DNA synthesis (Metz 2008). The other manifestation is a raised homocysteine blood level; a deficiency in either or both nutrients deactivates the methylation of homocysteine to methionine, and results in an elevated homocysteine blood level, which is known to be a risk factor of cardiovascular disease (Scott 1999). Vegetarians have higher homocysteine levels than omnivores (Majchrzak *et al*. 2006; Su *et al*. 2006; Obeid *et al*. 2002). Nevertheless, it is not clear whether the raised homocysteine levels of the vegetarians have an adverse effect on cardiovascular disease as in omnivores, because vegetarians generally have a favorable risk profile of cardiovascular disease compared to omnivores except for high homocysteine levels.

1.7 Buddhism and vegetarianism

1.7.1 Buddhist vegetarianism

Buddhism is based on a teaching of Siddhartha Gautama (566 BC - 486 BC, India), called Buddha (Eckel 2010). Buddha means "those who have achieved enlightenment" (Keown 2003). The first of the five important Buddhist precepts is "do not kill or injure any living creature." But the precept "prohibition of meat eating" varies within Buddhist schools (Harvey 2000).

The Buddhism schools are basically classified into Hinayana (or Theravada) and Mahayana. Hinayana Buddhism predominates in Sri Lanka, Myanmar, Thailand, Laos, and Cambodia. Mahayana Buddhism is widely disseminated in China, Korea, Japan, Taiwan, Vietnam, Bhutan, Nepal, Tibet, and Mongolia (McGovern 2003; Keown 1996).

Meat eating and Hinayana (Theravada) Buddhism

Hinayana Buddhism, the closest to early Buddhism, does not strictly prohibit eating meat, but encourages vegetarianism. Buddha emphasized the precept, "do not kill," i.e. "it is worse to swat a fly than to eat the carcass of an already dead animal" (Harvey 2000).

As in early Buddhism, the monks in countries where Hinayana Buddhism is practiced do not prepare their own meals. Instead, they beg for food from house to house which is considered to be one of the most important Buddhist practices (Wijayaratna 1990). Furthermore, the monks convey merit (good karma) to those who offer food (Kittler and Sucher 2008). The monks are supposed to eat everything they receive through begging. They should not ask for or not selectively eat what they want, even if the food contains meat (Harvey 1990). Moreover, the monk is forbidden to ask for any meat and ten specific animals which were already prohibited by the society at the time of Buddha, such as elephants, horses, lions, snakes, and dogs (Faure 2009; Wijayaratna 1990). In the Buddhist sutra, the Buddha permits a monk only "pure" meat under three conditions: "If the monk has not seen, heard or suspected that the animal has been killed specifically for him" (Faure 2009). Besides, a monk who is very ill is allowed to eat fish or meat (Wijayaratna 1990).

Meat eating and Mahayana Buddhism

During the period from the death of Buddha to about the time of the beginning of the Christian era, Mahayana Buddhism developed (McGovern 2003). Unlike Hinayana Buddhism, Mahayana Buddhism except Vajrayana advocates "no eating food from dead animals" and "vegetarianism" (Harvey 1990). Meat eating in Mahayana Buddhism is considered as an indirect involvement in the killing of an animal, although the animal is not specially killed for himself (Faure 2009). Furthermore, the core of Mahayana Buddhism is compassion and meat eating 'extinguishes the seed of great compassion' (Harvey 2000). In addition to eating onion, leeks, scallions, garlic and chives, meat eating is regarded as impeding meditation (Yifa 2002).

Meat eating and Vajrayana Buddhism

Vajrayana Buddhism, which is a branch of Mahayana, dominates in Tibet, Bhutan, Nepal, and Mongolia (Bailey and Taitz 2006). Most of these Northern Buddhists, except for some Lamas, eat meat. They believe that Lamas who eat meat may perform a ceremony to lead the dead animal to a good rebirth (Harvey 2000). Moreover, vegetarian life in this region is not practical, because of the harsh, cold climate as well as an inappropriate environment for farming (Walters and Portmess

2001). Furthermore, livestock plays a important role in the economy of these regions (Harvey 2000).

1.7.2 Korean Buddhist vegetarianism and Temple food

According to a national survey in 2002, 50.7% of the population belonged to a religion, of which 23.2% were Buddhist. The Buddhist clergymen of 105 Buddhist sects and their 22,072 temples reported that the number of Buddhist nuns and monks was 15,224 and 26,008, respectively (Ministry of Culture and Tourism 2002).

The Buddhist nuns and monks represent the oldest and the most traditional vegetarian group in Korea. They mainly eat „Temple food," which is also served to temple visitors. More than twenty years ago, Korean Buddhist nuns and monks were vegans (Oh and Yoo 1978; Yoo *et al*. 1969). Modern Korean Buddhist nuns and monks still cook a vegan diet, however, occasionally consume milk, yoghurt, cheese or breads, cookies, and cakes, which often contain eggs or butter (Kim and Lee 2006; Park *et al*. 2002; Cho and Park 1994a; Cho and Park 1994b).

In general, the Korean Buddhist diet is characterized by the avoidance of

1) food of animal origin, except dairy products
2) five pungent vegetables (O Shin Tschae): garlic (*Allium sativum*), welsh onion (*Allium fistulosum*), wild garlic (*Allium monathun*), galic chives (*Allium tuberosum*), and asant (*Ferula asafoetida*)
3) alcohol
4) high amounts of processed food.

1.8 Background and aim of the study

Western vegetarians have been widely studied (Phillips 2005; Sabaté *et al*. 1999). Religious groups (e.g. SDA) in US-studies (Anonym 2007; Butler *et al*. 2007; Willett 2003) and nonreligious groups (e.g. health food shop users, members of vegetarian society) in Europe (Key *et al*. 2003; Appleby *et al*. 1999; Thorogood 1995) have been predominantly investigated. In comparison, the nutritional status of vegetarians in East Asia has not been widely studied.

The traditional Korean diet consists of mainly grains and other food of plant origin, and a moderate amount of food of animal origin (Lee and Ryu 1988). Therefore, a vegetarian diet draws less attention in Korea. However, the nutrition transition made a change in meat and animal food consumption (Kim *et al*. 2000). With reduced physical activity and an increased consumption of Western style food, the disease patterns in Korea have shifted as in Western countries (Lee *et al*. 2008; Lee and Sobal 2003; Lee *et al*. 2002). Moreover, food scandals such as BSE, foot-and-mouth disease and recently dioxin contamination decreased the trust in the safety of animal foods and increased the interest in a vegetarian diet (Hyun Hyun 2008). At the same time, the Buddhist vegetarian diet was receiving more attention. Between January 1990 and January 2008, a total of 722 newspaper articles on Buddhist cuisine were published and of these 98% were published since 2000 (Moon 2008).

The aim of this study was to determine the nutritional status of vegetarian Buddhist nuns who represent the oldest and the most traditional vegetarian group in South Korea and compare the results to omnivorous women. The dietary intakes, BMI, body composition, serum lipids status, and the nutritional status of iron, folate, and vitamin B_{12} were investigated. Furthermore, the relationships between these variables were analyzed.

2 Materials and Methods

2.1 Study population

A total of 178 female subjects (Figure 4) residing in Daegu and Gyeongbuk Province in South Korea voluntarily participated in the study between October 2002 and March 2003. Initially, 97 vegetarian Buddhist nuns aged 21-47 years, who had been adhering to a vegetarian diet according to Buddhist teaching, were recruited from two Buddhist temples (Unmun-Sa and Budo-Am). For a comparison group, 81 omnivorous women aged 19-57 years were enrolled; 41 Catholic nuns, whose lifestyles were similar, but whose dietary pattern differed from that of Buddhist nuns. Further, 40 female college students and laboratory technicians, who were not majoring in food and nutrition were included in the study. Both nun groups attend classes in particular programs: a 4 year-college course for Buddhist nuns and a

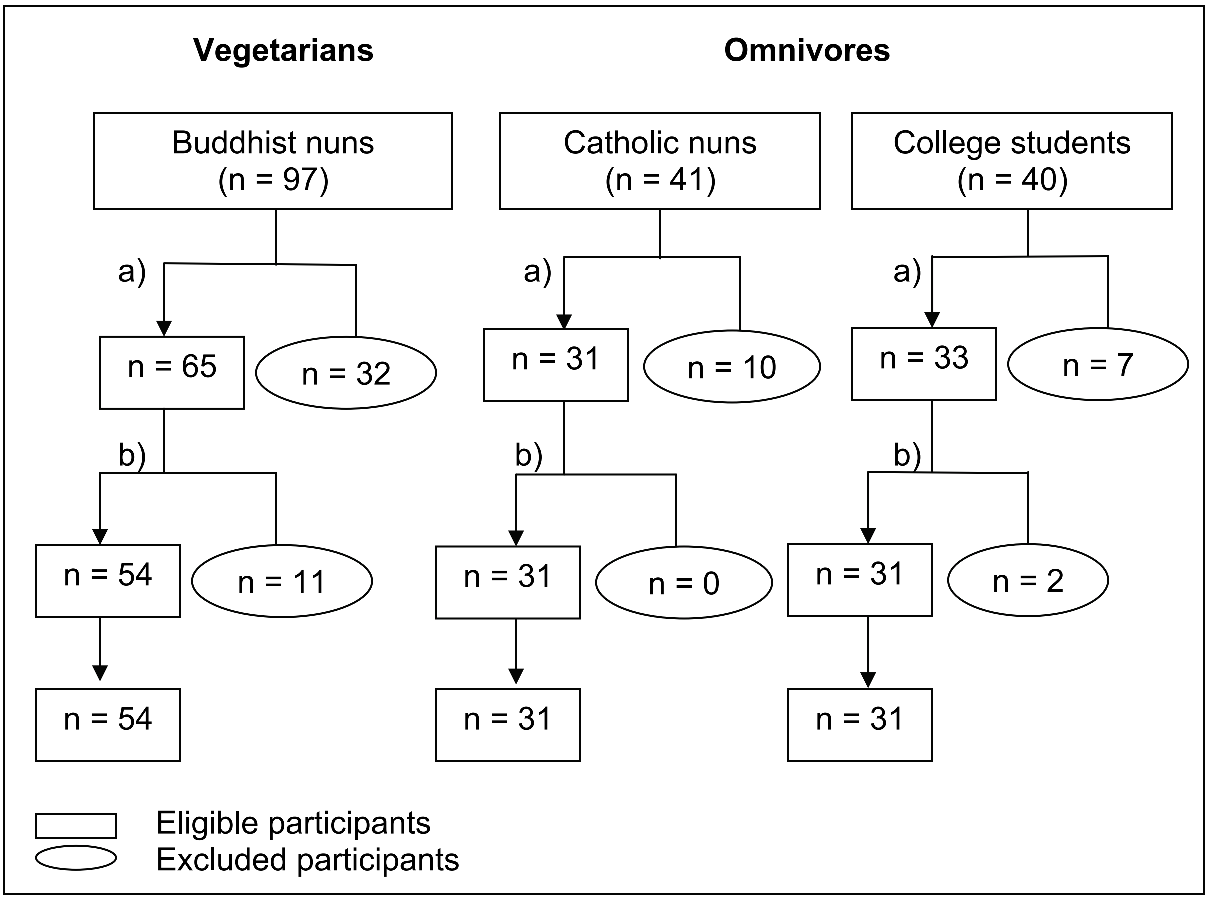

Figure 4: Study design

a) Inclusion criteria: 1) apparently healthy and non-smoking women; having no physician-diagnosed disease and taking no medication over the period of the study; 2) no use of dietary supplements for the last six months, 3) having regular menstrual cycles

b) Inclusion criteria: complete dietary records.

vocational training program for Catholic nuns. Since both religious groups belonged to a way of life with communal living in a temple or in a convent, the students and technicians were asked to join with friends with similar lifestyle and to share regularly at least one meal a day together.

The inclusion criteria were: 1) apparently healthy non-smoking women; having no physician-diagnosed disease (especially inflammatory disease) and no medication, 2) no use of dietary supplements (e.g. mineral and vitamin supplements or health foods) for the last six months, 3) having regular menstrual cycles, 4) completed dietary records. According to these criteria, 54 vegetarian Buddhist nuns, 31 omnivorous Catholic nuns, and 31 omnivorous female college students were enrolled.

At the end of a three day dietary record period, body composition was measured by bioelectrical impedance analysis, and blood samples were collected for serum lipids and hematological and biochemical indices.

2.2 Materials and Methods

2.2.1 Dietary assessment

The subjects were instructed to complete the estimated food record using household measures for three consecutive days and were informed about portion serving size with food models and photographs (Korean Dietetic Association 2002). In addition to the estimated amount of food intake, the main ingredients in the meals were recorded, and the nuns in charge of cooking were asked to provide the recipes of the vegetarian meals. Based on this information, the standardized recipes (Ministry of Health and Welfare 2000) were modified and entered into the nutritional program. Can-Pro 2.0 (Computer Aided Nutritional Analysis Program version 2.0, The Korean Nutrition Society, 2002, Seoul) was used for the analysis of dietary data.

2.2.2 Anthropometric and body composition measurements

Body height was measured to the nearest 0.1 cm and body weight to the nearest 0.1 kg using a digital scale integrated bioelectrical impedance analysis (BIA). The body mass index (BMI) was calculated as body weight in kilograms divided by the square of height in meters (kg/m^2).

The body composition was determined by a segmental multi-frequency-bioelectrical impedance analysis (SM-BIA) method (InBody 3.0, Biospace Co. Ltd, Korea). In contrast to single frequency whole body measurement, which assumes the body is a single cylinder, SM-BIA assumes the body consists of five cylinders (arms, legs, and trunk) and measures with an 8-point tactile electrode at frequencies of 5, 25, 250, 500 kHz (Figure 5). Using the multi-frequency analysis, intracellular water and extracellular water currents are measured separately. The precision and accuracy of the device were validated by other studies (Demura *et al*. 2004; Salmi 2003; Bedogni *et al*. 2002).

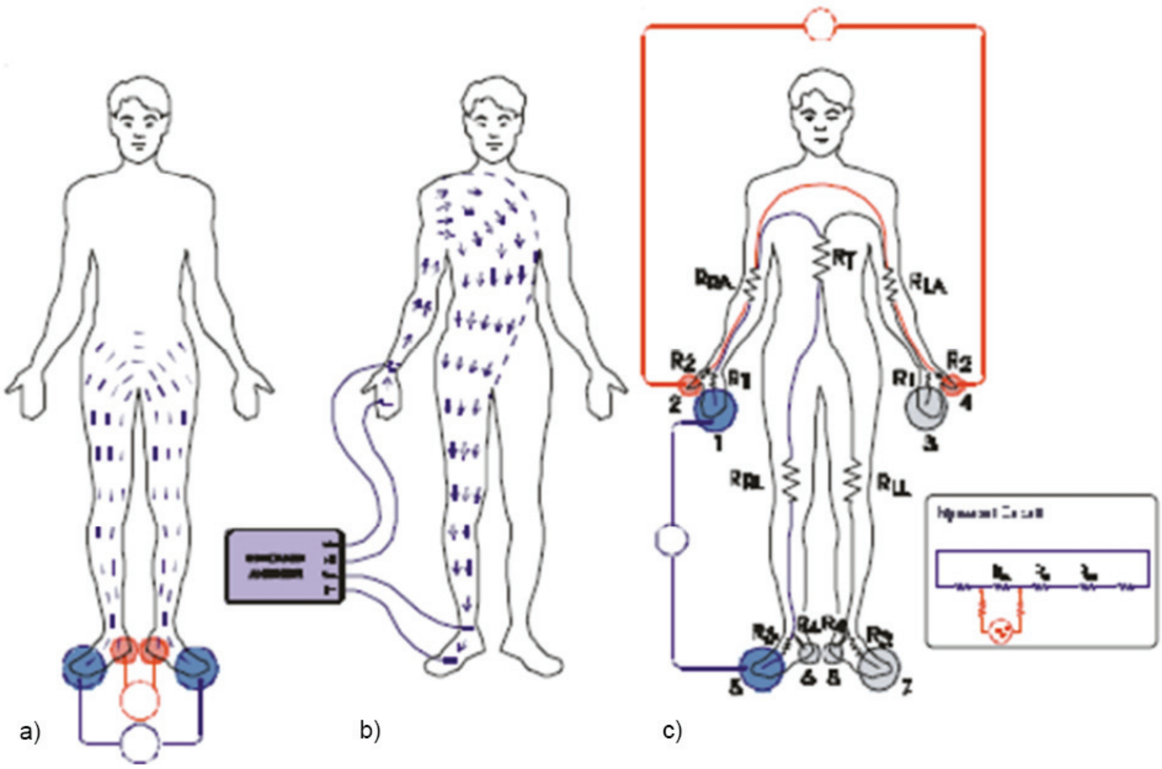

Figure 5: Example of segmental BIA models (Source: Biospace Co. Ltd. Technology leaflet)

After overnight fasting, the body composition of the subjects was measured as the subject stood on the foot electrodes (left, right anterior and posterior) and grasping the hand electrodes (left, right thumb and palm) (Figure 6). Height and age were entered into the BIA software, while body weight, body mass index (BMI, kg/m^2), fat free mass, and body fat were measured and calculated by the BIA software.

Figure 6: Inbody 3.0 (Source: Biospace Co. Ltd. Technology leaflet)

2.2.3 Blood parameter measurements

After overnight fasting, a venous blood sample was obtained from all participants. A complete blood cell count was determined by an automated hematology analyzer SE-9000 (TOA Medical Electronics, Kobe, Japan). Serum was prepared and frozen at -80°C until the testing was performed. Serum concentrations of ferritin, folate, and vitamin B_{12} were measured by an Electrochemiluminescence Immunoassay (ECLIA), using commercial kits (Elecsys Ferritin, Folate, vitamin B_{12} reagent kit, Roche Diagnostics, Mannheim, Germany) on the Elecsys 2010 analyzers (Roche Diagnostics, Mannheim, Germany). Serum concentrations of triglyceride, total cholesterol, low density lipoprotein and high density lipoprotein cholesterol were measured by a Chemical Autoanalyzer, Olympus AU 5400 (Olympus Optical Co Ltd., Tokyo, Japan) using commercial enzyme assay kits (Kyowa Medex, Tokyo, Japan).

World Health Organization criteria for anemia were used as the reference value (WHO *et al*. 2001): hemoglobin level < 120 g/l and hematocrit < 0.36. A serum ferritin level below 15 µg/ml is regarded as depleted iron stores (WHO *et al*. 2001). A mean corpuscular volume (fl) level below 80 (fl) is considered to be microcytosis, and over 100 (fl) is considered to be macrocytosis (Tefferi 2003).

According to suggestions from the WHO Technical Consultation on folate and vitamin B_{12} deficiencies (Anonym 2008), the cutoff value for defining deficiencies based on metabolic indicators was set at < 4 ng/ml serum folate and at < 203 pg/ml serum vitamin B_{12}.

2.2.4 Statistical analysis

Statistical analysis was performed using SPSS for Windows (version 17, Chicago, IL, USA). For group comparison, a one-way ANOVA test was used when the residuals were normally distributed (Kolmogorov-Smirnov test and Shapiro-Wilk test) and the variances were equal (Levene's test). If a significant difference between the groups existed, a post hoc test (Scheffe) was applied for a multiple comparison procedure that examined further differences between the groups (pair-wise comparison). When the assumptions of ANOVA were not met, the Kruskal-Wallis test was performed. As a post hoc test, Mann-Whitney U test for pair-wise comparison was used with Bonferroni's correction. The Jonckheere-Terpstra test assessed trend analysis for duration of vegetarianism and body fat. By calculating Pearson's chi-square in cross-tab, it was determined whether the frequency of cases outside the cutoff values was different among diet groups. Fisher's exact test was used when the expected value was less than five. After normal distribution tests, normally distributed data were assessed with Pearson's correlation and non-normally distributed data with Spearman's rank-order correlation coefficient. The variables were adjusted in partial correlation and regression analysis. A p value < 0.05 was considered statistically significant.

3 Results

3.1 Dietary intake

The macro- and micronutrient intakes from the three-day dietary records are presented in Table 5 and 6. The total energy intakes did not differ between the dietary groups. However, with the exception of plant fat intake, there were significant differences regarding the energy providing nutrients between the three dietary groups. In pair-wise multiple comparisons, Buddhist vegetarians and omnivorous Catholic nuns had a higher plant protein intake but a lower total protein intake than omnivorous college students. The omnivorous Catholic nuns had higher intakes of carbohydrates than vegetarians due to a high intake of fruits during the research period. Nevertheless, the vegetarians ingested more crude fiber. The omnivorous students consumed the highest amount of total fat and animal fat. The amount of their intake of polyunsaturated fatty acids (PUFA) was not significantly different from that of the vegetarians, but higher than that of the omnivorous Catholic nuns. Despite of the high intake of PUFA, the omnivorous students had the lowest ratio of PUFA to SFA due to their intake of saturated fatty acids (SFA). The cholesterol intake differed significantly between overall groups as well as between groups.

Regarding the micronutrient intakes (Table 6), there were significant overall differences in the dietary groups in the intake of niacin, vitamin B_6, vitamin C, folate, calcium, iron, and zinc. In multiple comparisons, Buddhist vegetarians and omnivorous students had higher niacin but lower zinc intake than omnivorous Catholic nuns. The vegetarians consumed more vitamin B_6 and folate than both omnivore groups. The omnivorous Catholic nuns had the highest vitamin C intake, twofold more than the omnivorous students. The highest median intake of folate was found in vegetarians. The folate intake of students was only 52% that of the vegetarians. The intake of total calcium and of total and plant iron of Buddhist vegetarians and omnivorous Catholic nuns were higher than those of omnivorous students. The Buddhist vegetarians had the highest and the omnivorous college students had the lowest intake of plant calcium. Conversely, the vegetarians had the lowest and the omnivorous students had the highest iron intake from animal origin. There were no significant differences in intakes of vitamin B_1, vitamin B_2, vitamin A, and vitamin E.

Table 5: Macronutrient intakes from the three-day dietary record

	Buddhist vegetarians (n = 54)	Omnivores (n = 62)		*p*-value
		Catholic nuns (n = 31)	College students (n = 31)	
Energy (kcal)	1756 [1371-2021]	1867 [1628- 2103]	1753 [1100-2285]	n.s§
Protein, in % energy	11.7[a] [11.1 – 12.8]	11.5[a] [10.8 – 12.4]	14.9[b] [14.0 – 15.7]	< 0.001§
Carbohydrates, in % energy	72.3[a] [67.1 – 76.1]	75.2[a] [72.5 – 77.1]	58.2[b] [55.4 – 61.1]	< 0.001§
Fat, in % energy	16.0[a] [12.3 – 19.8]	13.0[a] [11.8 – 16.2]	26.9[b] [24.0 – 29.0]	< 0.001§
Total protein (g)	51.6[a] (13.3)	55.8[a] (9.39)	65.8[b] (12.5)	< 0.001†
• Plant protein (g)	47.2[a] [37.2 – 58.2]	40.1[a] [36.5 – 48.2]	26.6[b] [24.0 – 30.4]	< 0.001§
• Animal protein (g)	2.5[a] [0.3 – 5.2]	11.3[b] [9.9 – 14.6]	39.0[c] [30.2 – 43.4]	< 0.001§
CHO (g)	312.9[a] [252.6 – 371.9]	355.5[b] [306.4 – 383.7]	253.4[c] [230.8 – 279.8]	< 0.001§
Crude fiber (g)	9.3[a] [7.0-11.4]	7.6[b] [6.6-8.9]	4.3[c] [4.0-4.9]	< 0.001§
Total fat (g)	32.3[a] (13.2)	30.5[a] (9.4)	52.2[b] (12.5)	< 0.001†
• Plant fat (g)	27.0 [19.7 – 36.1]	23.4 [18.4 – 27.5]	24.5 [17.1 – 28.0]	n.s§
• Animal fat (g)	2.3[a] [0.1 – 6.8]	5.2[b] [3.4 – 8.8]	25.0[c] [19.2 – 34.1]	< 0.001§
SFA (g)	3.1[a] [2.0 – 6.0]	3.0[a] [2.6 – 4.9]	9.1[b] [6.4 – 12.7]	< 0.001§
MUFA (g)	3.5[a] [2.1 – 5.3]	4.2[a] [3.7 – 4.7]	9.5[b] [7.4 - 12.3]	< 0.001§
PUFA (g)	5.9[a] [3.5 - 8.4]	4.8[ab] [3.5 - 8.4]	6.6[ac] [5.7 – 9.2]	0.001§
P/S ratio	2.3[a] [1.7 – 3.0]	2.2[a] [1.3 – 2.4]	0.9[b] [0.7 – 1.7]	< 0.001§
Cholesterol (mg)	10.8[a] [3.4 – 29.8]	70.0[b] [56.7 – 117.4]	330.8[c] [221.5 – 418.0]	< 0.001§

CHO Carbohydrates, SFA, saturated fatty acids, MUFA monounsaturated fatty acids, PUFA polyunsaturated fatty acids, P/S ratio of polyunsaturated fatty acids, and saturated fatty acids

† One-way ANOVA, § Kruskal-Wallis test, n.s not significant, $p > 0.05$.

The data are presented as mean (SD) using one-way ANOVA and as median [1.-3. quartile] using Kruskal-Wallis test. Means or medians with different superscript letters are significantly different between groups after post hoc test (significant level: Scheffe 0.05, Bonferroni's correction 0.017). Means or medians with the same superscript letter are not significantly different between groups after post hoc test.

Table 6: Micronutrient intakes from the three-day dietary record

	Buddhist vegetarians (n = 54)	Omnivores (n = 62)		*p*-value
		Catholic nuns (n = 31)	College students (n = 31)	
Vitamin B_1 (mg)	1.1 (0.3)	1.2 (0.3)	1.0 (0.2)	n.s[†]
Vitamin B_2 (mg)	0.9 [0.7 – 1.1]	0.8 [0.7 – 1.0]	0.9 [0.8 – 1.1]	n.s[§]
Niacin (mg)	13.9[a] [11.0 – 16.2]	11.2[b] [10.5 – 13.4]	14.0[a] [11.6 – 17.1]	0.002[§]
Vitamin B_6 (mg)	2.1[a] [1.8 – 2.5]	1.8[b] [1.6 – 2.1]	1.8[b] [1.5 – 1.9]	0.003[§]
Vitamin C (mg)	145[a] [111-211]	197[b] [141-286]	79.2[c] [57.9-102.1]	< 0.001[§]
Folate (µg)	340[a] [296-430]	267[b] [241-347]	177[c] [152-219]	< 0.001[§]
Vitamin A (µg RE)	631.3 [478.6 – 842.4]	547.7 [457.7 – 636.6]	613.8 [515.1 – 682.2]	n.s[§]
Vitamin E (α-TE)	12.1 [9.3 – 15.6]	11.4 [9.0 – 13.0]	12.8 [10.4 – 15.2]	n.s[§]
Total calcium (mg)	524.1[a] [426.6 – 695.0]	519.0[a] [457.2 – 595.1]	406.1[b] [312.4 – 599.8]	0.008[§]
• Plant calcium (mg)	436.7[a] [348.4 – 561.8]	344.3[b] [316.1 – 396.1]	206.2[c] [167.1 – 242.5]	< 0.001[§]
• Animal calcium (mg)	69.8[a] [8.3 – 149.9]	153.6[b] [140.9 – 205.9]	211.8[b] [107.8 – 346.9]	< 0.001[§]
Total iron (mg)	14.1[a] [10.9-17.3]	15.2[a] [12.4-21.6]	10.0[b] [8.9-11.9]	< 0.001[§]
• Plant iron (mg)	14.1[a] [10.7-17.1]	14.0[a] [10.7-20.3]	6.8[b] [5.2-8.3]	< 0.001[§]
• Animal iron (mg)	0.1[a] [0.0-0.2]	1.0[b] [0.8-1.3]	3.2[c] [2.6-4.0]	< 0.001[§]
Zinc (mg)	8.0[a] [5.9 – 9.5]	9.5[b] [8.5 – 10.5]	7.5[a] [6.9 – 9.1]	< 0.001[§]

RE Retinol Equivalent, α-TE α-Tocopherol Equivalent

[†] One-way ANOVA, [§] Kruskal-Wallis test, n.s not significant, $p > 0.05$.

The data are presented as mean (SD) using one-way ANOVA and as median [1.-3. quartile] using Kruskal-Wallis test. Means or medians with different superscript letters are significantly different between groups after post hoc test (significant level: Scheffe 0.05, Bonferroni's correction 0.017). Means or medians with the same superscript letter are not significantly different between the groups after post hoc test.

Vitamin B_{12} intake in the study was not directly calculated due to a lack of Korean national food data on vitamin B_{12}. Therefore, to assess the vitamin B_{12} intake of vegetarians, the amount of Korean laver (*Porphyra tenera*), purple algae, and dairy product intake was considered (Table 7). The Buddhist vegetarians almost exclusively consumed foods of plant origin except for some dairy products. Thus, the dietary source of vitamin B_{12} from animal foods in our vegetarians came exclusively from dairy products. Additionally, Korean laver (*Porphyra tenera*), most commonly consumed in Korea, is known to contain active vitamin B_{12} and is regarded as a plant source of vitamin B_{12} (Miyamoto *et al*. 2009; Kwak *et al*. 2008; Yamada *et al*. 1999). There was an overall difference in laver intake between the dietary groups. In pair-wise comparison, the vegetarian and the omnivorous nuns had a significantly higher laver intake than the omnivorous college students. The range of the dairy product intake in all diet groups was very wide. Hence, even though the omnivorous students had the highest median value of dairy products intake, there was no significant overall difference between groups.

Table 7: Intake of laver and dairy products

	Buddhist vegetarians (n = 54)	Omnivores (n = 62)		*p*-value[§]
		Catholic nuns (n = 31)	College students (n = 31)	
Laver (g)	1.3[a] [0.5-2.4]	1.3[ab] [1.0-2.0]	0.7[ac] [0.4-1.3]	0.005
Dairy product (g)	21.7 [5.0-67.1]	37.5 [32.0-115.0]	66.7 [0.0-156.7]	n.s

[§] Kruskal-Wallis test, n.s not significant, $p > 0.05$.
The data are presented as median [1.-3. quartile] using Kruskal-Wallis test. Medians with different superscript letters are significantly different between the groups after post hoc test (Bonferroni's correction 0.017). Medians with same superscript letter are not significantly different between the groups after post hoc test.

Figures 7 and 8 illustrate the proportion of energy, protein, iron, and calcium intake from plant and animal origin. The energy intake from plant origin in Buddhist vegetarians, omnivorous Catholic nuns, and college students was 98%, 95%, and 77%, respectively. The proportions of iron intake of the nuns groups were similar to that of energy intake; the omnivorous students consumed 32% of their iron intake from animal origin. The differences in protein and calcium origin between dietary groups were more obvious. The college students had more than 50% of their protein and calcium intake from animal origin, while the protein and calcium intake from milk and milk products in the vegetarian group were 5% and 15%, respectively. The values of omnivorous Catholic nuns were intermediate.

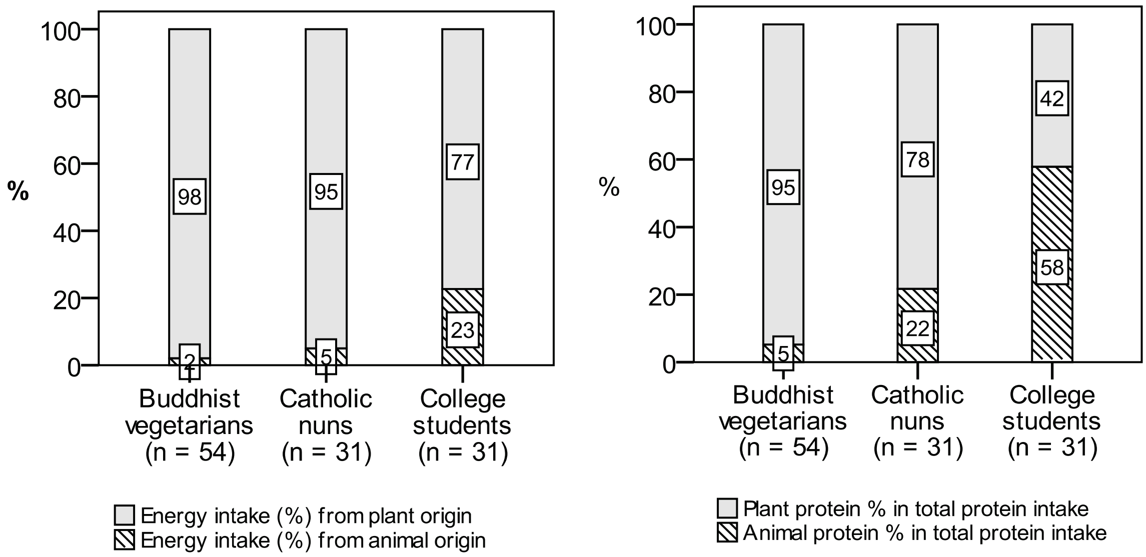

Figure 7: Median energy (%) and protein intake (%) from plant and animal origin

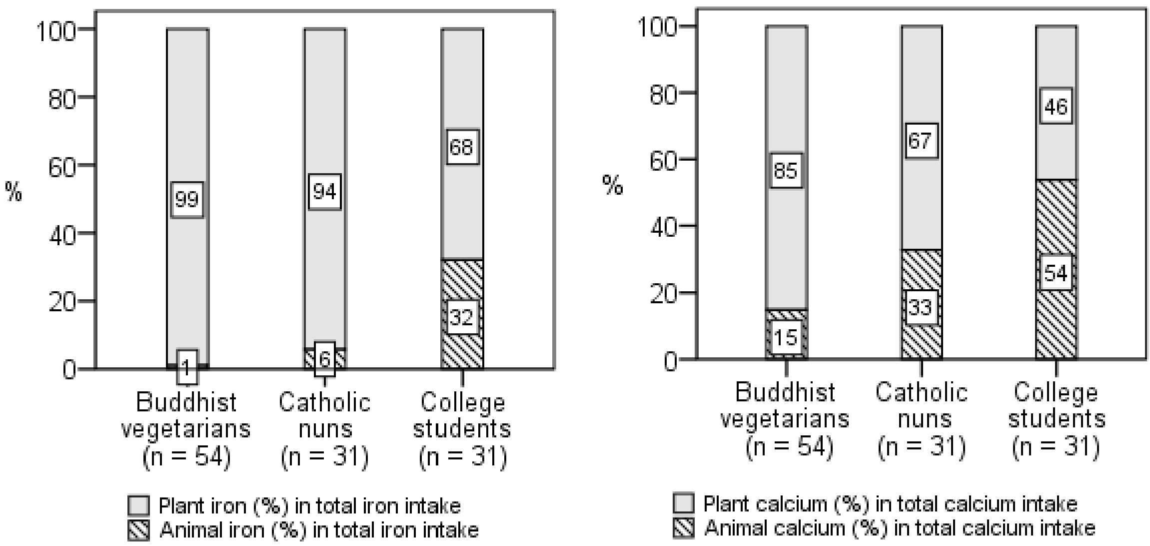

Figure 8: Median iron (%) and calcium intake (%) from plant and animal origin

Figures 9 and 10 present the dietary sources of iron and folate. The three major food groups of iron sources amounted to 77-78% in all diet groups. These were grains, vegetables including sea vegetables, and legumes in Buddhist vegetarians and omnivorous Catholic nuns. The omnivorous students received their iron not only from grains and vegetables but also from animal source foods, which accounted for 31% of total iron intake.

The main dietary sources of folate in vegetarians were vegetables including sea vegetables and other groups, especially spices (78%). The omnivorous Catholic nuns had a folate intake mostly based on vegetables and legumes (75%). The omnivorous students consumed dietary folate, not only in vegetables, but also in various relatively evenly distributed food groups. Of these, 11% came from animal source foods, and 15% from other groups such as potatoes, nuts, and beverages, and little from spices.

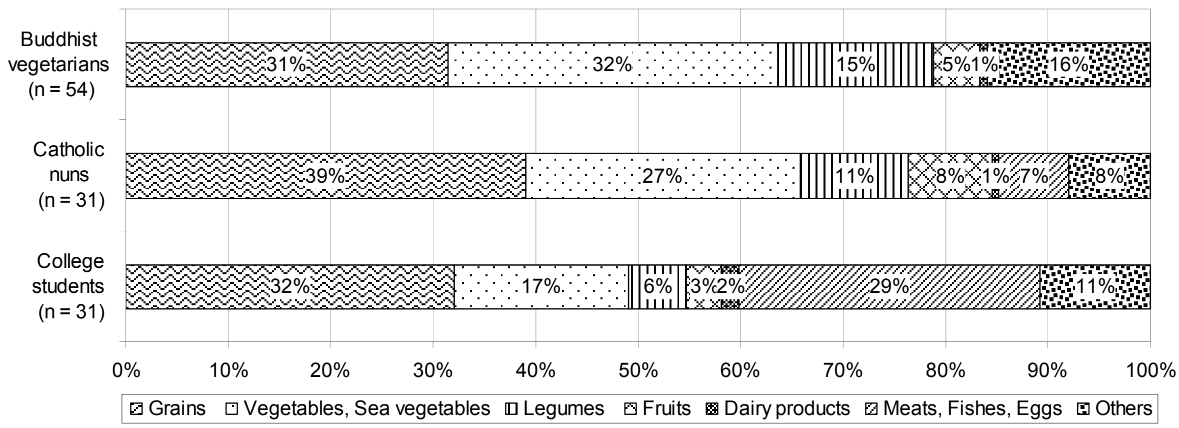

Figure 9: Dietary sources of iron (%)

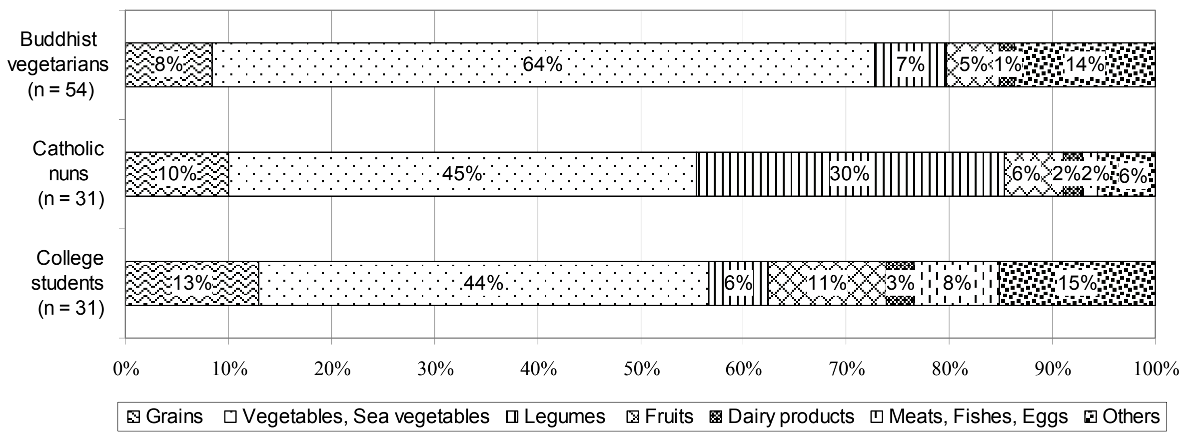

Figure 10: Dietary sources of folate (%)

3.2 Body composition

The values of anthropometry and body composition using BIA are presented in Table 8. There was a significant difference in age between the diet groups. The vegetarian and omnivorous nun groups were older than the omnivorous college students. The duration of vegetarianism ranged from 3 to 34 years.

Table 8: Anthropometry and body composition by BIA

	Buddhist vegetarians (n = 54)	Omnivores (n = 62)		*p*-value
		Catholic nuns (n = 31)	College students (n = 31)	
Age (y)	30^{a} [26.0 – 34.3]	31^{a} [28.0 - 34.0]	21^{b} [19.0-22.0]	< 0.001§
Duration of vegetarianism (y)	6.5 [4.0 - 13.0]	-	-	-
Height (cm)	160.0 [158.8 - 164.0]	160.0 [156.0 – 162.0]	161.0 [158.0-164.0]	n.s§
Body weight (kg)	58.5^{a} (7.1)	53.8^{b} (8.2)	52.2^{b} (4.9)	< 0.001†
Total body water (kg)	30.6^{a} [28.9 – 32.1]	28.8^{ab} [27.4 – 31.7]	27.9^{b} [26.3 - 29.2]	< 0.001§
Fat free mass (kg)	44.3^{a} [41.8 – 46.6]	41.6^{ab} [39.7 – 45.8]	40.3^{b} [38.1 – 42.3]	< 0.001§
Body fat (kg)	13.8^{a} [10.8 – 16.4]	11.7^{a} [8.5 – 15.3]	11.6^{a} [8.7 – 15.3]	0.040§
Body fat (%)	23.6 (5.3)	21.8 (5.9)	22.8 (4.7)	n.s†
BMI (kg/m²)	22.6^{a} [20.5 - 24.1]	20.7^{b} [18.9 - 22.2]	19.9^{b} [18.8 - 21.0]	< 0.001§

† One-way ANOVA, § Kruskal-Wallis test, n.s not significant, $p > 0.05$.
The data are presented as mean (SD) using one-way ANOVA and as median [1.-3. quartile] using Kruskal-Wallis test. Means or medians with different superscript letters are significantly different between groups after post hoc test (significant level: Scheffe 0.05, Bonferroni's correction 0.017). Means or medians with the same superscript letters are not significantly different between groups after post hoc test.

The median body height did not differ between the groups. However, the vegetarians had a significantly higher body weight and BMI (kg/m^2) than the omnivorous groups, whereas there was no difference between the omnivorous groups. Total body water and fat free mass of vegetarians were higher than those of both omnivorous groups, but not different from those of omnivorous Catholic nuns after Bonferroni's adjustment. There was an overall difference of body fat among the three groups. In pair-wise comparison, however, each difference between two groups is not apparent after adjustment. The median values of anthropometry and body composition between the omnivorous groups did not differ as well.

The median BMI of both vegetarians and omnivores fell into the normal range (WHO 2000). The BMI values were classified according to WHO-criteria (WHO 2000). As illustrated in Figure 11, 80% of the vegetarians and 74% of each omnivorous group were in the normal range (18.5-24.9 kg/m^2). The prevalence of underweight cases (BMI < 18.5 kg/m^2) in the omnivorous group was higher than in the vegetarian group, while the vegetarians showed tendencies of preobesity (25.0-29.9 kg/m^2). None of the omnivores and one vegetarian fell into the classification of grade I obesity (30.0-34.9 kg/m^2).

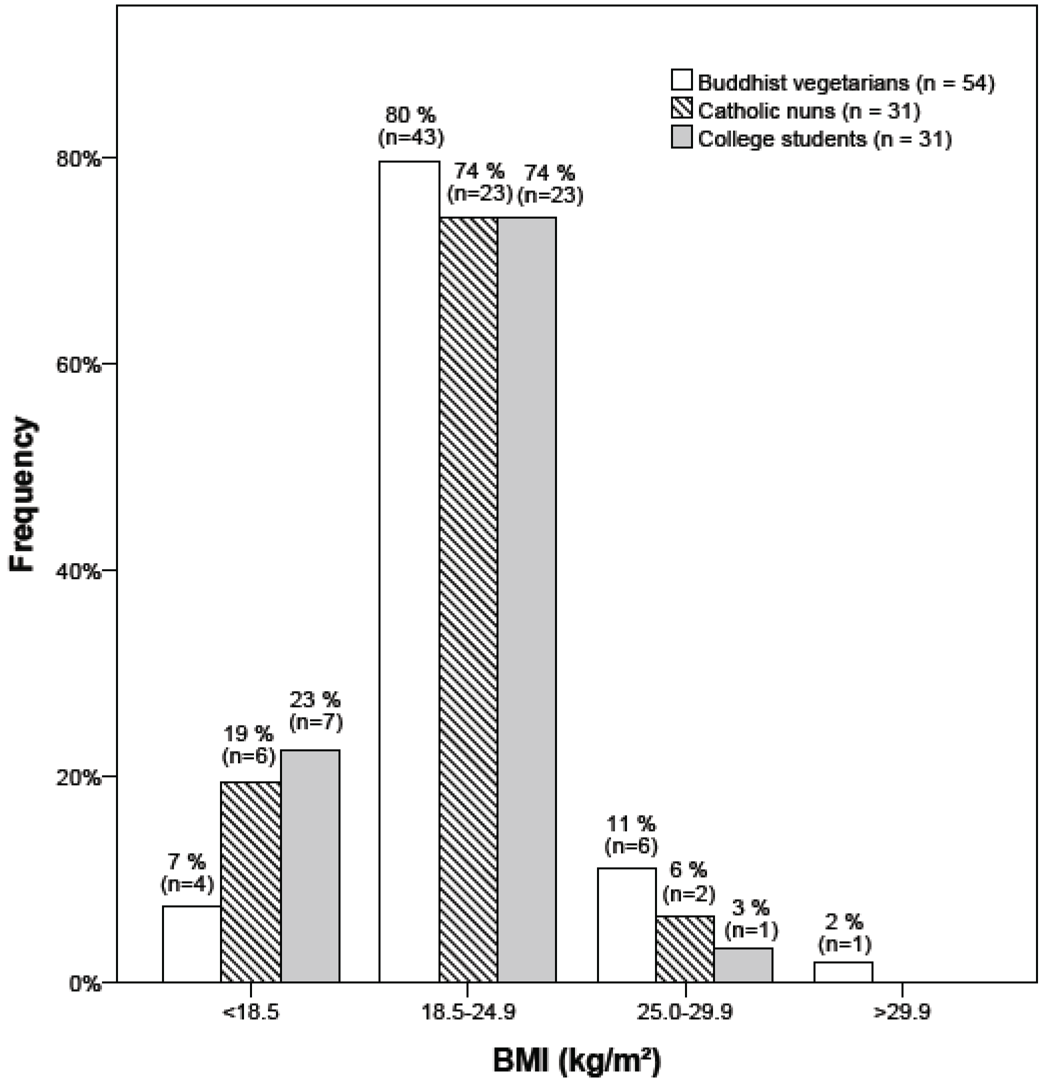

Figure 11: BMI-classification according to WHO-criteria (BMI in kg/m²) (WHO 2000)

Within the similar BMI range, the vegetarians tended to have lower body fat than the omnivores. The body composition values of the vegetarians within the normal range (18.5-24.9 kg/m^2) were compared with those of omnivores (Catholic nuns and college students added in the same range) (Table 9). Within this range, there was no difference in the body fat value between both dietary groups (*t* test, p = 0.121), although the vegetarians still had a significantly higher body weight, fat free mass, and BMI than the omnivores.

Table 9: Body composition within the normal range of BMI (18.5-24.9 kg/m^2)

	Vegetarians (n = 43)	Omnivores* (n = 46)	*p* value
Height (cm)	161.0 [158.0-164.0]	160.5 [158.0-163.3]	n.s
Weight (kg)	57.4 [54.7-60.0]	54.3 [49.9-58.1]	0.004
Fat free mass (kg)	43.8 [41.8-45.9]	41.2 [39.6-43.8]	0.001
Body fat (kg)	13.7 (3.34)	12.6 (3.19)	n.s^{t}
BMI (kg/m²)	22.1 (1.62)	20.9 (1.54)	< 0.001§

Normally and non-normally distributed data are presented as mean (SD) and median [1. - 3. quartile], respectively.
^{t} *t* test, No superscript Mann-Whitney U test, n.s not significant, p > 0.05.
* Omnivores added Catholic nuns and college students

The duration of vegetarianism was divided into three groups: 3-4 years as short, 5-10 years as middle, and 11-34 years as long. The body fat of these groups is depicted in Figure 12. The Jonckheere-Terpstra test showed that the body fat of vegetarians tended to decrease with the duration of vegetarianism (p = 0.043). In addition, the long duration group of vegetarians had a lower body fat than the short duration group (12.l vs. 15.0 kg, *t* test, p = 0.032). The short duration group tended to have a higher mean BMI (22.9 vs. 21.4 kg/m^2, *t* test, p = 0.069), mean body weight (60.3 vs. 55.7 kg, *t* test, p = 0.054), and mean fat free mass (45.3 vs.43.6 kg, *t* test, p = 0.231) than the long duration group, but it was not statistically significant.

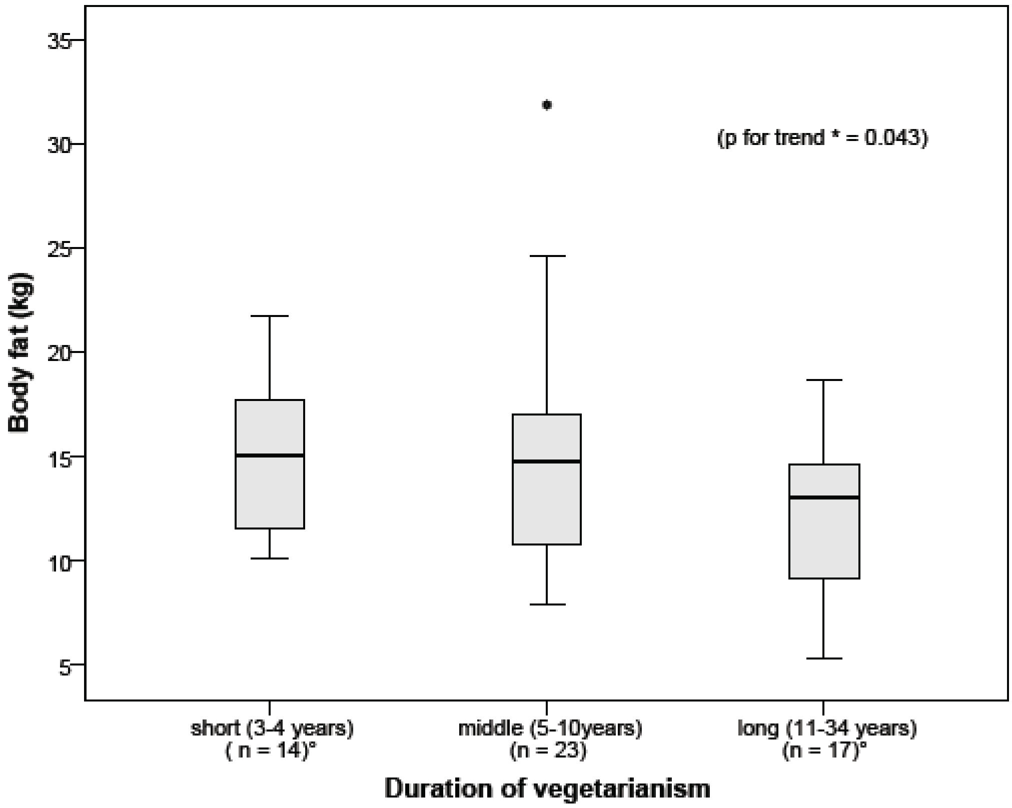

Figure 12: Body fat (kg) of vegetarians by the duration of vegetarianism
***Jonckheere-Terpstra test, ° *t* test (*p* = 0.032)**

3.3 Serum lipids

The results of serum lipid values are shown in Table 10. All means or medians of serum lipid values fell into the normal reference range according to NCEP (National Cholesterol Education Program (Table 11) (NCEP and ATP III 2001). There was an overall difference in values of total cholesterol, HDL cholesterol, and triglycerides between the groups. In multiple comparisons, vegetarians had lower total and HDL cholesterol levels than both omnivorous groups. Furthermore, there was no difference in those cholesterol levels between the omnivorous groups. In pair-wise comparisons of triglyceride levels, the levels of Buddhist vegetarians did not differ from those of the omnivore groups, and the college students had lower levels than the Catholic nuns. There was no significant overall difference in the LDL cholesterol and LDL/HDL cholesterol ratio between the groups. Although the groups did not always show statistically significant differences, the omnivorous Catholic nuns had a tendency towards the highest level of serum lipids, except for HDL cholesterol; the omnivorous college students had the intermediate and the vegetarians the lowest values.

Table 10: Comparison of serum lipid levels between dietary groups

	Buddhist vegetarians (n = 54)	Omnivores (n = 62)		*p*-value
		Catholic nuns (n = 31)	College students (n = 31)	
Total CHOL (mg)	156.0[a] (30.3)	175.3[b] (23.6)	170.7[b] (24.5)	0.004[†]
• LDL CHOL (mg)	88.4 (24.3)	100.8 (23.0)	94.8 (22.1)	n.s[†]
• HDL CHOL (mg)	56.8[a] (13.2)	65.3[b] (13.7)	70.3[b] (12.0)	< 0.001[†]
• LDL/HDL CHOL ratio	1.5 [1.2 – 2.0]	1.6 [1.3 – 1.8]	1.4 [1.1 – 1.7]	n.s[§]
• Triglyceride (mg)	75.0[a] [52.8 – 97.0]	83.0[ab] [68.0 – 104.0]	63.0[ac] [53.0 – 73.0]	0.023[§]

CHOL cholesterol, LDL low density lipoprotein, HDL high density lipoprotein,
[†] One-way ANOVA, [§] Kruskal-Wallis test, n.s not significant, $p > 0.05$.
The data are presented as mean (SD) using one-way ANOVA and as median [1.-3. quartile] using Kruskal-Wallis test. Means or medians with different superscript letters are significantly different between the groups after post hoc test (significant level: Scheffe 0.05, Bonferroni's correction 0.017). Means or medians with same superscript letter are not significantly different between the groups after post hoc test.

Table 11: Classification of serum lipid levels (Source: NCEP and ATP III 2001)

Total cholesterol (mg/dl)	< 200	Desirable
	200-239	Borderline high
	≥ 240	High
LDL cholesterol (mg/dl)	< 100	Optimal
	100-129	Near or above optimal
	130-159	Borderline high
	160-189	High
	≥ 190	Very high
HDL cholesterol (mg/dl)	< 40	Low
	≥ 60	High
Triglycerides (mg/dl)	< 150	Normal
	150-199	High
	≥ 500	Very high

Figure 13 illustrates the frequencies of cases outside the optimal ranges. The total and LDL cholesterol levels of both omnivorous groups were more frequent above the optimal range than those of the vegetarian group. Only 7% of vegetarians had their total cholesterol level ≥ 200mg/dl. The total cholesterol levels of all subjects are below 239mg/dl, except for one vegetarian (237mg/dl). The omnivorous students had the most frequent cases of LDL cholesterol value ≥ 100mg/dl, all their values were lower than 130mg/dl. In contrast, the LDL cholesterol concentrations of 7% of vegetarians and 6.4% of catholic nuns ranged between 100-159mg/dl. Five vegetarians had HDL cholesterol level lower than 40mg/dl. Nevertheless, their total and LDL cholesterol levels were lower than 200mg/dl and 100mg/dl, respectively. Therefore, their ratios of LDL and HDL cholesterol were also lower than three. The HDL cholesterol levels of all omnivores were higher than 40mg/dl. In addition, 35% of vegetarians, 58% of omnivorous Catholic nuns (n=18) and 84% of omnivorous college students had the high levels of HDL cholesterol (≥ 60mg) reducing the risk for coronary heart disease. All vegetarians and omnivorous college students had ratios of LDL and HDL cholesterol lower than three; however, two omnivorous Catholic nuns had a higher value than three. Whereas triglyceride levels of all college students were lower than 150mg/dl, 11% of vegetarians and 7% of Catholic nuns had their triglyceride level higher than 150mg/dl.

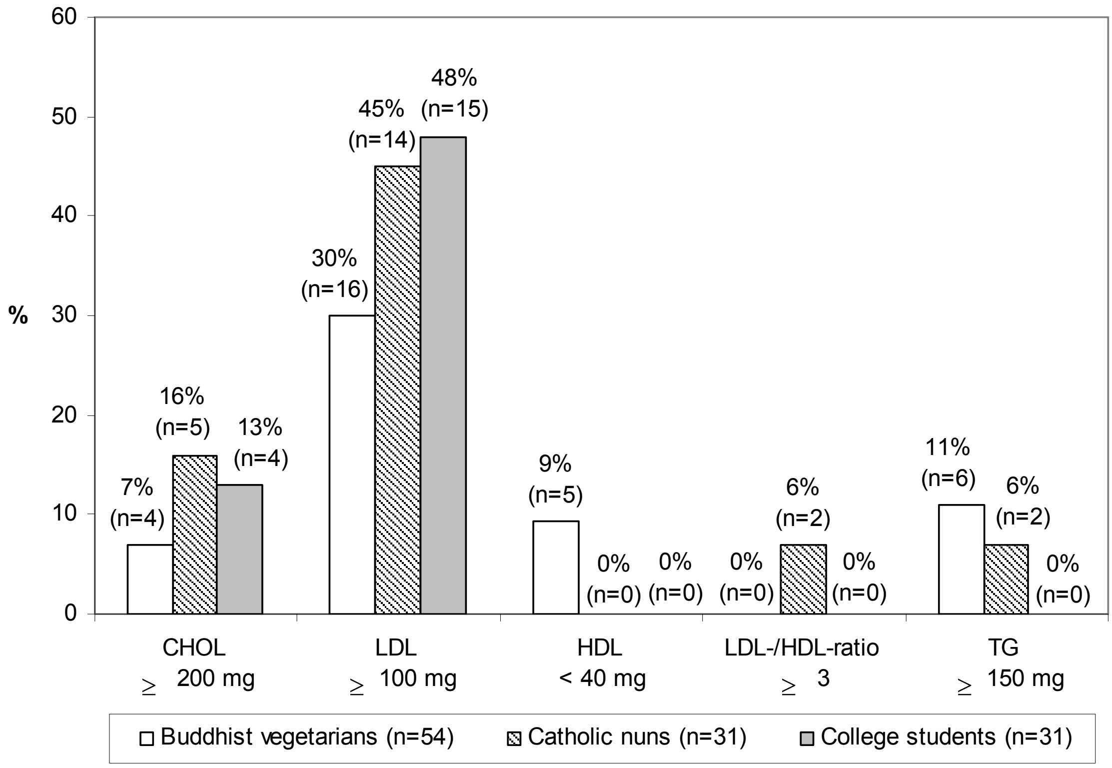

Figure 13: Frequencies of cases outside the optimal ranges

3.4 Hematological and biochemical indices of iron, folate, and vitamin B_{12}

The values of hematological and biochemical indices for iron, folate, and vitamin B_{12} are presented in Table 12. The medians of all blood parameters in all diet groups were within the normal reference ranges (Table 13).

Table 12: Hematological and biochemical indices

	Buddhist vegetarians (n = 54)	Omnivores (n = 62)		*p*-value
		Catholic nuns (n = 31)	College students (n = 31)	
WBC (x10^3/µl)	6.5^a [5.5 – 7.8]	5.8^b [4.7 – 6.8]	6.6^{ab} [5.4 – 7.6]	0.030§
RBC (x10^6/µl)	4.1 (0.3)	4.2 (0.2)	4.2 (0.3)	n.s†
Hemoglobin (g/l)	129 (9)	131 (10)	129 (9)	n.s†
Hematocrit	0.37^a (0.02)	0.39^b (0.02)	0.38^a (0.02)	< 0.001†
MCV (fl)	91.1^a [88.6 – 92.8]	94.4^b [92.5 – 96.9]	91.8^a [86.9 – 93.1]	< 0.001§
MCH (pg)	31.3 [30.6 – 32.5]	31.6 [30.8 – 32.2]	31.1 [29.8 – 31.8]	n.s§
MCHC (g/dl)	34.6^a [34.0 – 35.3]	33.3^b [32.8 – 34.1]	34.2^c [33.6 – 34.5]	< 0.001§
RDW (%)	12.5 [12.1 – 12.9]	12.6 [12.2 – 12.9]	12.9 [12.4 – 13.4]	n.s§
Platelet count (x10^3/µl)	274.0^a [247.3 – 303.0]	245.0^b [211.0 – 279.0]	256.0^{ab} [220.0 – 290.0]	0.042§
S-ferritin (ng/ml)	20.6^a [13.8 – 32.8]	37.3^b [24.3 – 57.4]	23.9^{ab} [16.5 – 47.1]	0.001§
S-folate (ng/ml)	10.1^a [8.2 – 13.0]	8.7^a [7.9 – 11.0]	6.9^b [5.0 – 7.9]	< 0.001§
S-vitamin B_{12} (pg/ml)	488.1^a [388.8 – 601.3]	713.7^b [571.8 – 864.8]	661.4^b [575.6 – 903.6]	< 0.001§

WBC White blood cell count, RBC Red blood cell count, MCV Mean corpuscular volume, MCH Mean corpuscular hemoglobin, MCHC Mean corpuscular hemoglobin concentration, RDW Red blood cell distribution width, S- serum.

† One-way ANOVA, § Kruskal-Wallis test, n.s not significant, $p > 0.05$.

The data are presented as mean (SD) using one-way ANOVA and as median [1.-3. quartile] using Kruskal-Wallis test. Means or medians with different superscript letters are significantly different between groups after post hoc test (significant level: Scheffe 0.05, Bonferroni's correction 0.017). Means or medians with the same superscript letters are not significantly different between groups after post hoc test.

Among the blood parameters for iron status, the level of blood cell count (RBC), hemoglobin, mean corpuscular hemoglobin (MCH), and red blood cell distribution width (RDW) did not differ between the groups. The omnivorous Catholic nuns had the highest level of hematocrit and mean corpuscular volume (MCV) and no difference in these values between vegetarians and omnivorous students were apparent. The level of white blood cell count (WBC) and platelet of vegetarians were higher than those of Catholic nuns and were not different from those of college students. The Buddhist vegetarians had the highest mean corpuscular hemoglobin concentration (MCHC) and the Catholic nuns had the lowest, and the students had an intermediate one.

The serum ferritin level of vegetarians was lower than that of omnivorous Catholic nuns; however, it did not differ from that of omnivorous students. Catholic nuns had a higher serum ferritin level than the students; however, after Bonferroni's adjustment there was no difference between the omnivorous groups found.

The omnivorous students had the lowest and the vegetarian group the highest level of serum folate. After Bonferroni's correction, there was no significant difference in serum folate level between Buddhist and Catholic nuns. In contrast, the vegetarian group had the lowest serum vitamin B_{12} level, and the difference between the omnivorous groups did not show.

Table 13: Reference range of hematological indices (adapted from Estridge *et al.* 2000; WHO/UNICEF/UNU 2001; Cook *et al.* 1992)

	Reference range (female adult)
WBC	$4.5\text{-}11.0 \times 10^9$/L
RBC	$4.0\text{-}5.5 \times 10^{12}$/L
Hemoglobin	120-160 g/L
HCT	0.36-0.48
MCV	80-100 fL
MCH	27-32 pg
MCHC	32-37%
RDW	11-15%
Platelet count	150 – 400 $\times 10^3$/µL

The frequency of cases outside the cutoff values (%) is shown in Table 14. Using the Pearson's chi-square test and Fisher's exact test, we determined whether there are differences in the frequencies of cases outside the cutoff values among the diet groups. Except for hematocrit (Pearson's chi-square value 6.494, p = 0.039), the different diets did not lead to statistically significant differences in hematological and biochemical indicators. Nevertheless, the frequencies of the hemoglobin, hematocrit, and serum ferritin below the cutoff values in the three groups were very similar: the vegetarians tended to have the most frequent prevalence, the omnivorous Catholic nuns the least frequent and the omnivorous students the intermediate.

The hemoglobin level of all subjects that had a value below 120g/L ranged from 100 to 119g/L. One subject from each group had a hemoglobin level below 110g/L and microcytosis. None of the vegetarians and omnivorous students but one Catholic nun had macrocytosis. With respect to vitamin deficiency, one vegetarian was vitamin B_{12} deficient, and one student was folate deficient.

Table 14: Outside the cutoff values (%) of hematological and biochemical indicators

	Buddhist vegetarians (n=54)	Omnivores (n = 62)		*p*-value
		Catholic nuns (n=31)	College students (n=31)	
Hemoglobin < 120 (g/l)	22 %	7 %	13 %	n.s$^{\$}$
Hematocrit < 0.36	30 %	7 %	19 %	0.039$^{\#}$
MCV < 80 (fl)	2 %	3 %	3 %	n.s$^{\$}$
MCV > 100 (fl)	0 %	3 %	0 %	n.s$^{\$}$
Serum ferritin < 15 (ng/ml)	28 %	7 %	19 %	n.s$^{\#}$
Serum folate < 4 (ng/ml)	0 %	0 %	3 %	n.s$^{\$}$
Serum vitamin B_{12} < 203 (pg/ml)	2 %	0 %	0 %	n.s$^{\$}$

$^{\#}$ Pearson's chi-square test, $^{\$}$ Fisher's exact test, n.s not significant, $p > 0.05$

3.5 Relationship between parameters

Body composition and dietary intake were hardly related. After energy and body weight adjustment, fiber intake of the omnivorous students had an inverse correlation with body fat (*r* = -0.371, *p* = 0.040) and a positive correlation with fat free mass (*r* = 0.385, *p* = 0.033). In vegetarians, body fat had no association with age (*p* = 0.854), but was inversely associated with the duration of vegetarianism (*r* = -0.272, *p* = 0.047), although the duration of vegetarianism had a positive association with age (*r* = 0.326, *p* = 0.016).

3.5.1 Relationship between body composition and serum lipids

The total and LDL cholesterol in all groups showed no relationship with body composition (Table 15). The LDL/HDL cholesterol ratio was positively associated with BMI in the vegetarian group (*r* = 0.279, *p* = 0.041) and with body fat percent in omnivorous Catholic nuns (*r* = 0.368, *p* = 0.042).

Table 15: Relationship between body composition and serum lipids

	Buddhist vegetarians (n = 54)	Omnivores (n = 62)	
		Catholic nuns (n = 31)	College students (n = 31)
HDL-cholesterol		• Fat free mass (+)* • Body fat (-)* • Body fat percent (-)	• Body weight (-)
Triglyceride			• Body weight (+) • Fat free mass (+) • Body fat (+)
LDL/HDL cholesterol ratio	• BMI (+)	• Body fat percent (+)	

* Body weight adjusted, significance level p < 0.05

In the omnivorous Catholic nuns, HDL cholesterol level had an inverse correlation with weight adjusted body fat (r = -0.385, *p* = 0.036) and body fat percent (*r* = -0.377, *p* = 0.037). Furthermore, fat free mass, after weight adjustment, correlated positively with HDL cholesterol (*r* = 0.393, *p* = 0.031).

In contrast, triglycerides of the omnivorous college students had a positive correlation with body weight, fat free mass, and body fat, whereas HDL cholesterol inversely correlated with body weight. After body weight adjustment, these correlations were not found.

3.5.2 Relationship between dietary intake and serum lipids

Energy adjusted cholesterol and animal protein intake in both vegetarian nuns and omnivorous Catholic nuns were highly correlated with their cholesterol concentrations (Table 16). In vegetarians, energy adjusted cholesterol intake had a positive correlation with serum total cholesterol ($r = 0.350$, $p = 0.010$) as well as HDL cholesterol ($r = 0.324$, $p = 0.017$) concentrations. Furthermore, the HDL cholesterol concentration correlated positively with energy adjusted nutrients from animal origin such as animal protein, animal fat, and saturated fat. In contrast, the intake of plant nutrients such as plant protein, carbohydrate, and fiber intake in vegetarians had an inverse association with serum concentration of total and HDL cholesterol as well as triglycerides. After energy adjustment, intake of these plant nutrients and serum lipids did not show any associations. On the other hand, a negative correlation between serum triglyceride concentration and animal protein intake of vegetarians was still apparent after energy adjustment ($r = -0.334$, $p = 0.014$).

In omnivorous Catholic nuns, serum cholesterol concentrations and nutrient intake were well correlated after energy adjustment. Serum total and LDL cholesterol had a highly positive correlation with the intake of cholesterol ($r = 0.382$, $p = 0.034$ and $r = 0.450$, $p = 0.011$), animal protein ($r = 0.515$, $p = 0.003$ and $r = 0.651$, $p < 0.001$), and total protein ($r = 0.385$, $p = 0.036$ and $r = 0.455$, $p = 0.010$). Furthermore, serum LDL concentration correlated negatively with carbohydrate intake ($r = -0.334$, $p = 0.014$) and the proportion of energy intake (%) from carbohydrates ($r = -0.418$, $p = 0.019$). The serum HDL cholesterol level had an inverse correlation with total protein intake, whereas the LDL/HDL cholesterol ratio had a positive association with animal protein and total protein.

In contrast to the vegetarian and omnivorous nun groups, dietary intake and the serum lipids of the omnivorous students were not well correlated. Fiber intake correlated inversely with HDL cholesterol and positively with the LDL/HDL cholesterol ratio. Carbohydrate and plant protein intake had a positive correlation with serum triglyceride concentration. After energy intake adjustment, however, these plant nutrient intakes and serum lipids were not related.

Table 16: Relationship between dietary intake and serum lipids

	Buddhist vegetarians (n = 54)	Omnivores (n = 62)	
		Catholic nuns (n = 31)	College students (n = 31)
Total cholesterol	• Energy (-) • Plant protein (-) • Carbohydrate (-) • Fiber(-) •Cholesterol (+)*	• Animal protein (+)* • Total protein (+)* • Cholesterol (+)* • Animal protein(%) from total protein (+)	
LDL cholesterol		•Animal protein (+)* • Total protein (+)* • Carbohydrates (-)* • Total fat (+)* • Cholesterol (+)* • E (%) from animal protein (+) • E (%) from carbohydrates (-) • Animal protein(%) from total protein (+)	
HDL cholesterol	• Animal protein (+)* • Animal fat (+)* • Saturated fatty acid (+)* • Cholesterol (+)* • Plant protein (-) • Total protein (-) • Carbohydrate (-) • Fiber(-) • E (%) from animal fat (+) • E (%) from animal origin (+)	• Total protein(-)* • Energy(%) from total protein (-)	• Fiber (-)
Triglyceride	• Carbohydrates (+) • Plant protein (+) • Fiber (+) • Animal protein (-)* • Animal protein(%) from total protein (-) • E (%) from animal protein (-)		• Carbohydrate (+) • Plant protein (+)
LDL/HDL cholesterol ratio		• Animal protein (+)* • Total protein (+)* • E(%) from animal protein (+) • Animal protein(%) from total protein (+)	• Fiber (+)

* energy adjusted, E(%) proportion of energy intake (%) , significance level $p < 0.05$

3.5.3 Relationship between dietary intake and hematological and biochemical indices

Except for an inverse correlation between serum folate concentration and age in vegetarians (*r* = -0.303, *p* = 0.026), blood variables were not correlated with either age in all diet groups or duration of vegetarianism in vegetarians (Table 17).

In vegetarians, the energy adjusted vitamin C intake had a positive correlation with both serum ferritin (*r* = 0.325, *p* = 0.017) and hemoglobin concentration (*r* = 0.339, *p* = 0.012). In contrast, the serum ferritin and energy intake (%) from total protein were negatively associated (*r* = -0.274, *p* = 0.045).

In omnivorous Catholic nuns, serum ferritin and hemoglobin concentration showed a strong inverse correlation with crude nutrient intake from plant sources such as plant iron, plant protein, and carbohydrates but not after energy adjustment. Furthermore, the serum ferritin concentration positively correlated with intake of animal protein (%) from total protein (*r* = 0.375, *p* = 0.037), energy intake (%) from animal source food (*r* = 0.437, *p* = 0.014), and animal source iron intake (%) from total iron (*r* = 0.494, *p* = 0.005). Hemoglobin concentration in omnivorous Catholic nuns had an inverse correlation with plant source iron intake from total iron (*r* = -0,373, *p* = 0.039). Conversely, in the student group, hemoglobin concentration was only positively correlated with iron intake from animal source foods (*r* = 0.369, *p* = 0.041). Iron intake and blood parameters in the omnivorous groups were not correlated after energy adjustment.

No relationships between serum folate concentration and nutrient intake were found in either vegetarians or omnivorous Catholic nuns. In contrast, the serum folate level in omnivorous students was positively associated with energy adjusted vitamin C intake (*r* = 0.385, *p* = 0.032) and negatively with energy intake (%) from animal fat (*r* = -0.403, *p* = 0.025).

Only in vegetarians, serum vitamin B_{12} was positively associated with laver intake (*r* = 0.341, *p* = 0.012), whereas this vitamin of the omnivorous students was associated with energy adjusted vitamin C intake (*r* = 0.408, *p* = 0.025). No association was found between serum vitamin B_{12} and the consumption of dairy product in all groups.

Table 17: Relationship between dietary intake and hematological and biochemical indices

	Buddhist vegetarians (n = 54)	Omnivores (n = 62)	
		Catholic nuns (n = 31)	College students (n = 31)
Serum ferritin	• Vitamin C (+)* • E(%) from total protein (-)	• Energy (-) • Carbohydrates (-) • Crude fiber (-) • Plant protein (-) • Plant fat (-) • Total iron (-) • Plant iron (-) • E(%) from animal protein (+) • E(%) from animal fat (+) • E(%) from animal source (+) • E(%) from plant source (-) • Plant iron(%) from total iron (-) • Animal iron (%) from total iron (+)	
Hemoglobin	• Vitamin C (+)*	• Plant iron (-) • Total iron (-) • Plant iron(%) from total iron (-) • Animal iron(%) from total iron (+)	• Animal iron (+) • Plant fat (-)*
Serum folate			• Vitamin C (+)* • Saturated fatty acids (-)* • Animal fat (-)* • E(%) from animal fat (-) • Animal fat(%) from total fat (-) • Plant fat(%) from total fat (+)
Serum vitamin B_{12}	• Laver (+)		• Vitamin C (+)

* energy adjusted, E(%) proportion of energy intake (%) , significance level $p < 0.05$

4 Discussion

A growing number of people in the world are living for various reasons as vegetarians. Of these, Buddhist vegetarianism is one of the oldest on the basis of the core teaching “do not kill any living creature” and “compassion.” Therefore, Buddhist vegetarianism, especially in early Buddhism, was not oriented to health. Since the monks and nuns in Mahayana Buddhism are not begging for food but cook for themselves in the temple, they developed the cooking methods according to their rules. In the Buddhist Sutra (Ekottaragama), “All rules in the world begin from the taking of food. Beings do not exist without food” (Lee 2007; Seo 1995). According to Buddhist teaching, food should be regarded as nourishment for meditation practice, not an object for enjoyment and craving (Lee 2003). For over two thousand years, Buddhist monks and nuns have been consuming Temple food, which is traditionally based on plant food only, and have maintained their health. Nowadays “Temple food” or “Buddhist diet” is getting attention as healthy food (Moon 2008).

Dietary pattern

In accordance with Buddhist precepts, the Buddhist nuns basically adhered to a vegan diet and only occasionally consumed dairy products. Although they may unintentionally and irregularly consume small amounts of eggs from snacks i.e. breads, cookies, and cakes, eggs are principally not on the list of cooking ingredients. Therefore, they can be classified as lacto-vegetarians. The amounts of their food consumption from animal source foods, however, were comparable with those of Western “moderate German vegans” (Waldmann *et al*. 2003).

The median age of nuns groups differed statistically significantly from that of the students. However, all subjects have the same energy and nutrient requirements. Therefore, this statistical difference has little impact on the results.

The omnivorous Catholic nuns had a higher percentage of energy and nutrient intake from plant origin than the female population in the similar age group (Table 18). But the ratio of plant to animal calcium intake was similar to that of the female population in the age group 30-49 years. The omnivorous students and the female population in the age group 20-29 years had similar proportions of energy and iron intake from plant sources, whereas the percentages of protein, fat and calcium intake from animal sources of students were higher than those of the female population.

Table 18: The proportion of energy and nutrient intake from plant and animal sources

Energy and nutrient	Food sources	NHNS*		Omnivores	
		20-29 years	30-49 years	Catholic nuns	College students
Energy intake from	plant (%)	80.4	82.8	95.0	77.3
	animal (%)	19.6	17.2	5.0	22.7
Protein intake from	plant (%)	50.6	54.0	78.3	42.2
	animal (%)	49.4	46.0	21.7	57.8
Fat intake from	plant (%)	53.7	53.2	83.0	48.3
	animal (%)	46.3	46.8	17.0	51.7
Calcium intake from	plant (%)	58.6	65.0	67.3	46.2
	animal (%)	41.4	35.0	32.7	53.8
Iron intake from	plant (%)	69.9	70.2	94.2	67.8
	animal (%)	30.1	29.8	5.8	32.2

* The Korean National Health and Nutrition Survey (KHIDI and MHW 2003)

In comparison, German females in the age group of 19-25 years and 25-51 years had 26% and 28% of their energy intake from animal source foods, respectively (DGE 2004). In Germany, this proportion tends to increase by age, whereas in Korea it tends to decrease by age.

The intakes of carbohydrates and fat display an obvious contrast between the Western and the Korean diet. Additionally, Korean vegetarians as well as omnivores have a higher carbohydrate intake and a lower fat intake than other Asians (Hung *et al*. 2006; Cha 2001; Lee *et al*. 2000; Chiu *et al*. 1997; Pan *et al*. 1993).

Although the consumption of grain products has been declining continuously, grain products still play a major role in the high carbohydrate intake in Korea. The National Health and Nutrition Survey reported that the average intake of grain products was 306 g and it accounted for 58% of the total energy intake (KHIDI and MHW 2003). The omnivorous Catholic nuns in the present study had a slightly higher intake of carbohydrates than the Buddhist vegetarians. This was due to the high consumption of fruits during the study period. But the intake of grain and sugar products as well as the proportion of energy intake from carbohydrates did not differ between the nun groups. Whether vegetarian or not, the consumption of rice and other grain products in Korea does not differ much between diet groups. This is consistent with other Korean studies on the SDA vegetarians (Son and Choue 2006; Kim *et al*. 2004; Choi *et al*. 1999). Nevertheless, Buddhist vegetarians consumed more crude fiber than omnivores due to a higher consumption of vegetables with low energy density.

During the rapid economic development in low- and middle-income countries, a dramatic transition and adaptation to the Western dietary habits (“westernization”) has occurred (Popkin 2002). As in other Asian countries, the dietary patterns in Korea have changed rapidly; the consumption of animal source foods has increased. However, meat dishes are still often cooked with traditional methods (i.e. stewing, grilling, and roasting) and commonly used or served with vegetables. Vegetables also play a crucial role in the Korean cuisine and there are few dishes without some vegetables (Lee *et al*. 2002). In fact, Korea has the highest consumption of vegetables among the Asian countries (Kim and Popkin 2000). Traditionally vegetables are salted and fermented with various spices such as garlic or chili powder which is known as Kimchi. Despite the decreasing consumption of this food by the young generation, all types of Kimchi amounted to 44% and Chinese cabbage Kimchi alone to 32% of total vegetable consumption (291g) in Korea (KHIDI and MHW 2003). Furthermore, vegetables are preferably served raw, fermented, blanched, or steamed instead of stir-fried like in Chinese style cooking (Kim *et al*. 2000). In addition to the individual adherence to traditional dietary pattern, efforts not only to preserve but also to develop a traditional Korean food style have been established at the regional and governmental level. Therefore, the dietary shift to “westernization” with a high fat intake has not occurred in Korea as drastically as in other Asian countries (Kim *et al*. 2000).

The low fat content of the Buddhist diets is a result of their cooking method based on the typical Korean cooking style (Kim and Lee 2006). In previous studies with the Buddhist nuns in the same Buddhist Temple in 1981 (Yoon and Lee 1982) and in 1997 (Cha 2001), the percentage of energy intake from fat was only 4.9% and 11.6%, respectively. Because Buddhist nuns rarely eat outside of their temple or consume processed foods, they maintain a relatively low energy intake from fat. Similarly, a previous Korean SDA study showed that the nutrient intake of SDA-college students who had a communal living and ate according to a well-planned lacto-ovo-vegetarian diet was due to the traditional cooking method. The distribution of energy intake from macronutrients was founded to be 70% carbohydrates, 16% protein, and 14% fat (Kang and Sung 1983).

The dietary sources of cholesterol and animal fat in Buddhist diets are breads, custard cream puffs, castella (sponge cake), muffins, doughnuts, cheese, yoghurt, and milk. The mean cholesterol intake was lower than that of Western female moderate vegans (Waldmann *et al*. 2005; Haddad *et al*. 1999; Draper *et al*. 1993). The type of snacks and the frequency of their consumption varied because most of them were irregularly donated by Buddhist followers. Thus, it was difficult to estimate the usual intake of cholesterol and animal fat. The total energy intake was also strongly influenced by the consumption of these snacks, containing relatively high amounts of fat and sugar.

Compared with the carbohydrate and fat intake, the difference in protein intake between the Asian and Western population is negligible; the protein intake of Buddhist vegetarians was comparable to other Asian vegetarians (Son and Choue 2006; Cha 2001; Lau *et al*. 1998; Pan *et al*. 1993) and Western vegans (Waldmann *et al*. 2005; Haddad *et al*. 1999; Draper *et al*. 1993).

The median calcium intake of all groups in the present study as well as of those in the National Health and Nutrition Survey did not reach the recommended levels (700mg) (The Korean Nutrition society 2005; KHIDI and MHW 2003). Calcium is one of the most frequent nutrient deficiencies in the Korean diet. Although the omnivorous students had the highest proportion of animal calcium (54%), they had the lowest calcium intake (406g) due to a low intake of plant calcium.

Dairy products are a good source of calcium and are readily available. Especially in Western countries, dairy products play an important role for achieving an adequate calcium intake. The German Nutrition Survey reported that dairy products accounted for about 50% of the calcium intake, and that bottled water ranked second with 15% (Mensink and Beitz 2004). In the USA, dairy products provided about 73% of the dietary calcium, whereas calcium from vegetables accounted to only 7% (USDA and CNPP 2004). In contrast, according to the National Health and Nutrition Survey, food from animal sources contributed 42% to the calcium intake (dairy products 18%, fish group 20%) while milk (75g) supplied the most calcium as a single food item (15%). Plant foods provided the remaining 58% of the calcium intake. Of these, vegetables were the leading source of calcium, namely 27.4 % (KHIDI and MHW 2003).

Although milk and milk products are ready available sources to achieve an adequate calcium intake, a high consumption of dairy products is not desirable because many studies showed a relationship with adverse health effects, such as prostate and ovarian cancer, type I diabetes, multiple sclerosis, and cow milk allergy (Lanou 2009).

The main inhibitors of calcium absorption from plant foods are oxalate and phytate. Therefore, the calcium bioavailability is very low in high-oxalate vegetables such as spinach and rhubarb, is intermediate in sweet potatoes, and high in low-oxalate vegetables such as bok choy, broccoli, and kale (Weaver *et al*. 1997). In contrast to other beans, calcium in soy products is also relatively highly bioavailable, although soybeans contain high amounts of oxalate and phytate. Calcium-set tofu has substantial amounts of bioavailable calcium (Weaver *et al*. 1999).

Unlike in Western countries, both the vegetarian diet and the traditional Asian diet primarily consist of vegetables and grains. Therefore, it is not surprising that there are no significant differences in the intake of foods of plant origin such as carbohydrates, plant fats, PUFA, vitamin C, vitamin E and PUFA between the vegetarians and the omnivores in this study, also as in the other Asian vegetarian studies (Hung *et al*. 2006; Son and Choue 2006; Choi *et al*. 1999; Huang *et al*. 1999).

Body composition

The vegetarians, especially the vegans in Western countries have a significantly lower BMI than the omnivores (Berkow and Barnard 2006; Key *et al*. 1999;). This difference is obvious when the omnivorous group is obese. In contrast, the Buddhist vegetarians in this study had higher body fat and BMI as well as higher fat free mass than the omnivorous group. This result was consistent with other Korean Buddhist vegetarian studies (Cha 2001; Yoon and Lee 1982); however, the reason was not clear. There was no correlation of body fat in Buddhist vegetarians with any nutrient or food intake. The intake of carbohydrates in vegetarian nuns was slightly lower than in omnivorous nuns and the intake of fat was also lower than in the omnivorous students. The sedentary activity of the Buddhist nuns was similar to that of the omnivorous groups because they were also studying and practicing meditation in a 4 year-college course for Buddhist nuns. Whether the previous BMI of vegetarians was higher than their present BMI was not asked.

Although Buddhist vegetarians in the study had a higher body weight and BMI than the omnivorous groups, the vegetarians tended to have lower body fat than the omnivores at a similar BMI range. Unexpectedly, the body fat of Buddhist vegetarians tended to decrease with the duration of vegetarianism. The long-term vegetarian group had less body fat than the short-term group. But fat free mass and BMI were not correlated with length of adherence to a vegetarian diet. Similarly, the German Vegan Study (Waldmann *et al*. 2003) showed that there was no significant difference in the BMI between strict and moderate vegans; however, the strict vegans had a significant lower body fat mass than the moderate ones.

Unlike Western vegetarian studies, Korean SDA and Chinese vegetarian studies often showed no difference in BMI between vegetarians and omnivores, especially in age matched female groups (Chung and Choi 2006; Fu *et al*. 2006; Son and Choue 2006; Kwok *et al*. 2005; Lee *et al*. 2000; Choi *et al*. 1999; Huang *et al*. 1999; Lau *et al*. 1998; Pan *et al*. 1993). Moreover, Korean omnivores were found with a much lower BMI than Western omnivores. In spite of a tendency for overweight in Buddhist vegetarians, the median BMI of the vegetarians (22.6 kg/m²) and percentage of body fat (23.5%) was still within the normal range and comparable with that of European vegetarians of similar age and even lower than that of US vegetarians (Spencer *et al*. 2003; Alewaeters *et al*. 2005; Key *et al*. 1999).

Serum lipids

High levels of blood triglycerides, total and LDL cholesterol, and low HDL cholesterol levels are the most important risk factors of coronary heart diseases (NCEP and ATP III 2001). Low levels of total and LDL cholesterol are one of the most beneficial health effects of a vegetarian diet. A large number of studies consistently show that a vegetarian diet has protective effects on mortality and morbidity of coronary and ischemic heart diseases (Fraser 2009; Chang-Claude *et al*. 2005).

There is very little data on serum lipids levels of vegetarian young women (20-39 years). Thus, the following studies used for comparison had a wide age range. In comparison to other Korean, Asian and Western vegetarian studies, Buddhist vegetarians in this study tended to have lower levels of total and LDL cholesterol and higher levels of HDL cholesterol (Lin *et al*. 2010; Chen *et al*. 2008; De Biase *et al*. 2007; Waldmann *et al*. 2005; Cha 2004; Lee *et al*. 2000; Li *et al*. 1999; Hong *et al*. 1996). The levels of total and LDL cholesterol of omnivores in this study were similar to those of omnivores in other Asian and lacto-ovo-vegetarians as well as vegans in Western countries. The total cholesterol concentrations seem to be more affected by dietary pattern or age than other serum lipids. The previous Buddhist vegetarian study showed that in the age group of 20-29 years, there were no differences in serum levels of LDL, HDL cholesterol, and triglycerides between vegetarians and omnivores. In contrast, total cholesterol levels of diet groups differ in all age groups (Cha 2004). Similarly, a German vegan study showed that there was a significant difference in total cholesterol, but LDL and HDL cholesterol levels did not differ between strict and moderate vegans (Waldmann *et al*. 2005).

The HDL cholesterol levels of Buddhist vegetarians had a positive correlation with total cholesterol levels. The vegetarians who had HDL cholesterol levels lower than 40 mg/dL had mostly low total and LDL cholesterol levels. Thus, their ratio of LDL to HDL cholesterol was lower than 2.5. The HDL cholesterol of omnivorous Catholic nuns had a positive correlation with fat free mass and an inverse correlation with body fat mass and the percentage of body fat. Consistently, serum HDL cholesterol levels and body fat showed an inverse association in other studies (Choi *et al*. 2003; Nagaya *et al*. 1999).

Although HDL cholesterol concentrations of Buddhist vegetarians in the present study were lower than those of omnivorous groups, the omnivores also had relatively high concentrations of HDL compared to other studies (Lin *et al*. 2010; Chen *et al*. 2008; De Biase *et al*. 2007; Waldmann *et al*. 2005; Cha 2004; Lee *et al*. 2000; Li *et al*. 1999; Hong *et al*. 1996). German lacto-ovo-vegetarians had slightly higher levels of HDL cholesterol, but the ratio of LDL to HDL cholesterol was much higher than in our vegetarians (Hoffmann *et al*. 2001). Compared to other vegetarians, the ratio of LDL to HDL cholesterol was more beneficial in Buddhist vegetarians as well as in omnivores in the present study (Li *et al*. 1999). Moreover, this ratio showed a positive association with BMI in vegetarians and with the percentage of body fat in omnivorous Catholic nuns.

The dietary cholesterol intakes of vegetarian and omnivorous nuns showed a positive association with their serum total cholesterol levels. Furthermore, the food intake from animal sources also had a positive correlation with HDL cholesterol levels in vegetarians and with LDL cholesterol levels in omnivorous nuns. These results are consistent with results of other studies on dietary intake and blood lipids (Katcher *et al*. 2009; Fraser 1994).

The omega-3-fatty acids are known to be a crucial dietary factor for beneficial blood lipid profiles and the prevention of heart disease (Simopoulos 2008; Katcher *et al*. 2009). Perilla seed oil, sea vegetables, walnuts, and soybean oil can be an important dietary source of omega-3-fatty acids from plant food for Buddhist vegetarians (Katcher *et al*. 2009; Rao *et al*. 2008; Simopoulos 2008). Flax and rape seeds also contain omega-3-fatty acids; however, they play only a minor role in the Korean cuisine.

In addition to the consumption of animal source food, the obvious difference in dietary pattern between Buddhist vegetarians and omnivores is the allium vegetable consumption such as garlic, onion, and scallion. Buddhist nuns and monks avoid these vegetables, because they disturb meditation practice. Of these, garlic is the most important seasonings in the Korean cuisine and the second most frequently consumed food item in Korea (KHIDI and MHW 2003). Garlic with its antioxidant compounds has an effect of reducing serum lipids as well as increasing HDL cholesterol concentrations (Kojuri *et al*. 2007; Tattelman 2005; Banerjee *et al*. 2003).

It is common in Asian studies that the levels of triglycerides of vegetarians do not differ from those of omnivores (Lin *et al*. 2010; Chen *et al*. 2008; Cha 2004; Lee *et al*. 2000; Hong *et al*. 1996). In our study, the serum triglyceride levels of vegetarians did not consistently differ from those of both omnivorous groups.

Serum triglyceride levels of Buddhist vegetarians showed an inverse correlation with animal protein intake. This may be the reason that HDL cholesterol and triglyceride levels were inversely correlated and HDL cholesterol levels correlated with animal source food (animal protein, animal fat and energy intake from animal food). Similarly, the triglyceride levels of the omnivorous students, who consumed the highest amount of animal source food and had the highest HDL levels, are lower than those of omnivorous nuns, who had a lower food intake from animal origin and higher triglyceride levels. In contrast, Western studies reported that a high intake of carbohydrates substituted for fat intake can lead to an increase of blood triglyceride levels (Parks and Hellerstein 2000). Similarly, carbohydrate intake in all subjects without subclassification in our study showed a positive association with serum triglyceride levels.

Iron, folate, and vitamin B_{12}

Iron, folate, and vitamin B_{12} are the crucial nutrients involved in active erythropoiesis, and their deficiencies result in decreased erythrocyte production consequently leading to anemia (Koury and Ponka 2004). The morphological characteristics of iron deficiency anemia are generally hypochromic and microcytic cells due to insufficient transport of hemoglobin to erythrocytes (Koury and Ponka 2004). In contrast, the anemia caused by folate or vitamin B_{12} deficiency is often characterized by macrocytosis due to immature erythrocytes (Metz 2008).

Iron

Although iron occurs abundantly in nature, it causes the most prevalent nutrient deficiency in the world (WHO *et al*. 2001). Iron deficiency and iron deficiency anemia have multifactorial causes: low dietary iron supply, high physiological requirement, and diseases, etc. Of these, dietary iron supply is determined by total iron intake, heme iron content, and bioavailability of nonheme iron (Cook 1990).

Iron from a meatless diet is generally less bioavailable than from an omnivorous diet. Nevertheless this diet has less effect on total iron intake (Hunt 2003). Similarly, the median of iron intake of vegetarian Buddhist nuns and omnivorous Catholic nuns in this study corresponded to Korean recommended daily intake (14mg) (The Korean Nutrition society 2005). In contrast, omnivorous students had the highest intake of iron from animal sources; however, the total iron intake was much lower than that of both groups of nuns and the recommended daily intake.

As in other vegetarians (Waldmann *et al*. 2004; Ball and Bartlett 1999; Shaw *et al*. 1995), grains, vegetables, legumes, and fruits were the main dietary sources of iron for the Buddhist vegetarians. Additionally, unlike Western vegetarians, they had an iron intake from sea vegetables (5%). Because sea vegetables contain little phytate, they are considered a good source of iron (Garcia-Casal *et al*. 2007; Joung *et al*. 2004). Besides, they contain vitamins, minerals, and trace elements, especially iodine which is also a nutrient of concern in vegetarian diets (Garcia-Casal *et al*. 2007; Tokudome *et al*. 2004; Ruperez 2002). In contrast, breakfast cereals which play an important role as an iron source for Western vegetarians (Waldmann *et al*. 2004; Ball and Bartlett 1999), were not consumed.

The dietary iron forms are divided into heme and nonheme iron. Of these, heme iron is mainly derived from hemoglobin and myoglobin in red meat, poultry, and fish, and amounts to about 40% of the total iron in animal tissues (Hunt 2005). It accounts for 5-15% of total iron intake in Western countries with high meat consumption (Nelson and Poulter 2004; Craig 1994; Hallberg 1981). Since heme iron is absorbed intact with the porphyrin ring, it is less affected by other dietary factors and highly bioavailable (Hunt 2005). The absorption rate of heme iron ranges from about 15-35% (Craig 1994). In our study, the hemoglobin and serum ferritin levels of omnivorous Catholic nuns and the hemoglobin levels of omnivorous college students showed a positive correlation with iron from animal source food. Otherwise, the omnivorous students had the highest intake of iron from animal source food yet the lowest intake of total iron and vitamin C. Their serum ferritin and hemoglobin concentrations did not differ statistically from that of Buddhist vegetarians who consume no heme iron, but they had high amounts of vitamin C. Heme iron itself is highly bioavailable and increases the bioavailability of nonheme iron. Nevertheless, that alone does not seem to lead to an optimal iron status (Harvey *et al*. 2005).

In Table 19, the dietary factors that inhibit or enhance nonheme iron uptake are presented. The main dietary iron form is nonheme iron. It accounts for 85-100% of dietary iron (Hunt 2005) and exists not only in plants (e.g. grains, legumes, vegetables, nuts, and seed) but also in animal source food (e.g. egg, milk, and animal products). Therefore, improving the bioavailability of nonheme iron plays a crucial role for an adequate iron supply in vegetarians as well as in omnivores.

Table 19: Dietary factors influencing absorption of nonheme iron in a vegetarian diet

		Food sources	Solution/ remarks
Inhibitor	Phytate	Grains, especially whole grains, legumes, seeds, nuts	Soaking, Germination, Fermentation
	Polyphenols/ tannins	Teas, coffees, wines	Do not consume at mealtime
	Oxalate	Spinach, some green leafy vegetables	Boiling, steaming
	Protein	Milk, egg, soy	Do not consume with iron rich meal
Enhancer	Vitamin C	Fruits, vegetables	Consume with diet rich in nonheme iron
	Inorganic acids	Fermented vegetables, fruits	

The absorption rate of nonheme iron ranges from 2-20% (Craig 1994) and is best when iron is present in the ferrous form ($Fe2^{+}$) and has a low molecular weight ligand in the intestinal lumen (Hunt 2005). Due to the low bioavailability of nonheme iron, those who consume little animal source food or have a diet with low iron bioavailability can eventually develop an iron deficiency (Denic and Agarwal 2007).

However, with increasing enhancing factors and decreasing inhibitory factors, the utilization of nonheme iron can be raised to a level similar to that of heme iron.

Iron absorption from vegetarian diets can be improved by modifying food preparation method, food selection, and meal combinations (Hunt 2003).

The strongest inhibitor of iron absorption is phytic acid. It comprises about 1-3% of cereal grains, legumes and nuts and is found in low concentration in roots, tubers, and vegetables (Sandberg 2002). In particular, whole grains and legumes supply high amounts of iron and other valuable nutrients (protein, zinc, calcium, and magnesium). Therefore, to improve the bioavailability of these nutrients, removal or degradation of phytate is useful. With food preparations such as soaking, germination, and fermentation, the phytate content in food can be decreased or removed (Hurrell 2004): With soaking, phytic acid in groundnuts can be reduced by 20% after 24 hours. During germination, the phytic acid concentration of cereal grains and legume seeds can be reduced by about 50%. Phytate was not found when grain was fermented after soaking and germination. The Korean cuisine is based on grain, legumes, and vegetables, therefore high phytate intake is expected. However, the main food group containing phytic acid is grains, especially white rice (Joung *et al*. 2004). White rice is the most frequently and most consumed food item in Korea. Despite its low iron content, white rice is the main iron source in Korea (KHIDI and MHW 2003). Furthermore, legumes and grains are usually soaked several hours before cooking. For instance, phytate content in soybean (1,283 mg/100 g) remains 201 mg in soft tofu, 239 mg in fermented soybean paste and 13mg in soybean sauce (Joung *et al*. 2004).

Spinach is one of the most important dietary sources of iron in Korea (KHIDI and MHW 2003). However, it is known to have a low iron bioavailability due to the high oxalate content. But a recent study reported that oxalate in spinach had inhibitory effects on the absorption of calcium but not iron. One of the iron salts in spinach, ferric oxalate, is very soluble, whereas calcium oxalate is insoluble (Bonsmann *et al*. 2008).

Polyphenols, in particular tannins present in teas, coffees, and wines also inhibit the iron absorption (75-85%) (Hallberg and Hulthen 2000). The absorption of nonheme iron from a meal is affected by other dietary factors from the same meal, but not those consumed several hours before (Hunt 2005). Therefore, in order to reduce the adverse effects of tea on iron absorption, tea should only be consumed at least 1 hour after a meal instead of with meals. This is particularly relevant to those with poor iron status or vegetarians who consume no heme iron (Nelson and Poulter 2004). In the Korean eating culture tea drinking at mealtime is very uncommon.

In contrast to animal tissue, animal protein in eggs and milk (bovine casein and whey protein) inhibits both heme and nonheme iron uptake (Hurrell *et al*. 1989; Hurrell *et al*. 1988).

Vitamin C is the strongest enhancer of iron absorption and can improve the iron bioavailability in natural and fortified foods against inhibitors such as phytate, polyphenols, calcium, and protein in dairy products (Hurrell and Egli 2010; Hunt 2005; Hallberg and Hulthen 2000). Vitamin C consumed with iron promotes to maintaining the iron in a soluble, reduced, low-molecular ligand form in the intestinal lumen (Hunt 2005). Thus, it can compensate for the low iron bioavailability in a vegetarian diet. In fact, vitamin C intake (with and without energy adjustment) of the Buddhist vegetarians in the present study was positively correlated with serum ferritin concentration. Additionally, although the omnivorous students with the lowest vitamin C intake consumed the highest amount of animal source food, their serum ferritin concentration did not differ from that of Buddhist vegetarians and tended to be lower than that of omnivorous Catholic nuns with a concurrent modest consumption of animal source food and a high intake of vitamin C. The Buddhist vegetarians consumed vitamin C in the winter season mostly from raw vegetables, fermented vegetables such as many kinds of Kimchi, dried vegetables, sea vegetables, and fruits.

In addition to dietary factors, iron stores have a strong effect on iron absorption. Both heme and non-heme iron are absorbed in inverse proportion to body iron stores. When iron stores are low, the absorption of nonheme iron (up to tenfold) is even more efficient than that of heme iron (up to twofold) (Cook 1990).

Since excess iron adds to free radical formation, it is not desirable and even deleterious. Furthermore, iron excretion is extremely restricted. In contrast to upregulation of intestinal iron absorption in iron deficiency, downregulation in excess iron intake seems to be ineffective (Conrad and Umbreit 2000). Therefore, lowering serum ferritin without any increasing iron deficiency anemia in vegetarians might be more favorable than high serum ferritin with excess iron intake in meat-eaters in Western countries (Hunt 2002).

Serum ferritin is the most sensitive indicator of depleted iron stores. The serum ferritin level of our vegetarians was comparable to that of other vegetarian women and higher than that of young vegan German women, whereas hemoglobin concentration was very similar (Waldmann *et al*. 2004; Obeid *et al*. 2002). It is consistent with other vegetarian studies that there is no significant difference in hemoglobin or serum ferritin concentrations between vegetarian and omnivorous women (Harvey *et al*. 2005; Obeid *et al*. 2002; Haddad *et al*. 1999; Shaw *et al*. 1995). Nevertheless, serum ferritin concentrations of vegetarians tend to be lower than those of omnivores.

Since ferritin is one of the acute-phase proteins increasing in the presence of infection or inflammation, the cutoff value for iron deficiency below 15 ng/ml may not be valid under inflammatory conditions (WHO and CDCP 2007). Although we did not determine acute-phase proteins, our subjects were asked for their disease history instead. In the analysis only subjects who were free of acute or chronic diseases and not taking any medication were included.

Folate

The median folate intake of all diet groups did not reach the amount of the Korean recommended daily intake (400 µg) (The Korean Nutrition society 2005). Nevertheless, the serum folate levels of all Buddhist vegetarians (range 6.30-20.0 ng/ml), omnivorous Catholic nuns (range 4.57-14.50 ng/ml), and omnivorous students (range 3.77-9.59 ng/ml) except one fell into the normal level (> 4 ng/ml). The serum folate level of the vegetarians in this study was lower than that of vegetarians in other studies (Herrmann *et al*. 2003; Obeid *et al*. 2002). One possible explanation could be that the blood samples were collected in the winter and early spring when dietary folate sources were limited, because serum folate concentration reflects recent dietary intake (Green 2008). Another reason could be that our subjects consumed no folate fortified foods but rather natural sources of folate such as vegetables, grains, and legumes.

Furthermore, a serum folate level > 20 ng/ml may not be desirable, especially combined with low serum vitamin B_{12} because it could mask a vitamin B_{12} deficiency ("folate trap") (Selhub *et al*. 2009). In fact, a higher prevalence of both anemia and cognitive impairment was associated with high serum folate (> 26 ng/L) in subjects with a low vitamin B_{12} status. By contrast, high serum folate in subjects having normal vitamin B_{12} status was associated with a protection from cognitive impairment (Morris *et al*. 2007).

Vitamin B_{12}

The natural dietary sources of vitamin B_{12} for vegetarians are dairy products and eggs, although milk contains very small amounts of vitamin B_{12}, and the bioavailability from eggs is low (Watanabe 2007; Chanarin and Metz 1997). Table 20 shows the vitamin B_{12} levels of dairy products and eggs. Milk, yogurt, and cheese that has not been aged have a lower content of this vitamin than aged and hard cheese. The vitamin B_{12} binding capacity of egg yolk is greater than egg white; however, vitamin B_{12} in egg yolk is surrounded by cholesterol (Craig and Pinyan 2001; Levine and Doscherholmen 1983). Furthermore, the bioavailability of vitamin B_{12} in eggs was even lower, especially in subjects with low vitamin B_{12} status (Carmel *et al*. 1988).

Table 20: Vitamin B_{12} levels in dairy products and eggs (Source: Elmadfa *et al*. 2007)

Food items	Active Vitamin B_{12} µg / 100 g
Fresh milk, 3.5% milk fat	0.4
Yogurt 3.5% milk fat	0.4
Double cream cheese	0.5
Speisequark 40%, 20% FDM and skimmed	0.7, 0.8, and 0.9
Chester, 50% FMD	1.0
Gouda	1.5
Cottage cheese	2.0
Camembert 60% 45% and 30% FDM	2.4, 2.8, and 3.1
Emmentaler 45% FDM	3.0
Chicken egg, whole	1.9
Chicken egg, yolk	2.0
Chicken egg, white	0.1

FDM, fat in the dry matter

In Western countries, the consumption of fortified foods is recommended for an adequate vitamin B_{12} supply for vegetarians, especially for vegans. Vitamin B_{12}-

fortified foods are breakfast cereals, soy and rice beverages, yeast, and meat analogs (Craig and Mangels 2009). As potential dietary sources of vitamin B_{12} for Asian vegetarians, plant foods such as fermented soy products and seaweeds have been investigated in many studies (Miyamoto *et al*. 2009; Kwak *et al*. 2008; Watanabe 2007; Yamada *et al*. 1996; Herbert 1988). In most of the studies either exclusively vitamin B_{12} analogs or traces of active vitamin B_{12} were detected. Exceptions were purple (*Porphyra sp.*) and green (*Enteromorpha sp.*) algae, in which substantial amounts of vitamin B_{12} were found (Miyamoto *et al*. 2009; Kwak *et al*. 2008; Watanabe *et al*. 2002; Yamada *et al*. 1999; Yamada *et al*. 1996).

The vitamin B_{12} content in laver varies, depending on the analysis method and the species (Watanabe *et al*. 2002). Korean laver (*Porphyra tenera*) is the most commonly consumed seaweed species in Korea as well as worldwide (McHugh 2003). As shown in Table 21, Kwak *et al* reported that 100 g of Korean laver products (*Porphyra tenera*) contained close to 70 µg of vitamin B_{12} (Kwak *et al*. 2008). With the same analytical method, Miyamoto *et al.* found a much higher content of vitamin B_{12} in Korean dried laver (*Porphyra tenera*) and a much lower content in seasoned and toasted laver than in previous studies (Miyamoto *et al*. 2009). Furthermore, no vitamin B_{12} analogs were found in this laver. Similarly, raw laver (*Porphyra tenera*) in the studies of Yamada *et al.* had a high proportion of active vitamin B_{12} from 73-100 %, whereas dried laver only had 35% active vitamin B_{12} (Yamada *et al*. 1999; Yamada *et al*. 1996).

Table 21: Vitamin B_{12} levels in seaweeds (Sources: [a] Kwak *et al* 2008; [b] Miyamoto *et al* 2009

Seaweeds	Vitamin B_{12} µg / 100 g
Korean laver (*Porphyra tenera*)	
Dried	66.76[a]/133.8[b]
Seasoned and toasted	51.7[b]
Sea lettuce (*Ulva lactua*)	84.74[a] (in dry weight)/ 9.41[a] (in wet weight)
Sea mustard (*Undaria pinnatifida*)	1.90[a]

The vitamin B_{12} bioavailability of laver in humans is still controversial. A Dutch study with children eating a macrobiotic diet (Dagnelie *et al*. 1991) found that laver (*Porphyra tenera*), spirulina, and fermented plant foods were not reliable sources of vitamin B_{12}. After consuming vitamin B_{12} from only these plant foods for 5 months, MCV in five vegan children was even higher, despite increasing plasma vitamin B_{12} levels. Methylmalonic acid is considered as the most important functional indicator for vitamin B_{12}, because vitamin B_{12} is necessary for the conversion of methylmalonyl CoA to succinyl CoA. In vitamin B_{12} deficiency, methylmalonic acid concentration is high in serum and urine (Selhub *et al*. 2008). A study on the vitamin B_{12} bioavailability of laver using methylmalonic acid showed that raw laver was a more reliable dietary source of vitamin B_{12} for vegetarians than dried laver (Yamada *et al*. 1999). However, in another study, six Japanese vegan children who daily consumed 2-4 g of dried laver had neither deficient vitamin B_{12} blood levels nor neurological disturbances (Suzuki 1995).

In contrast to other studies (Vogiatzoglou *et al*. 2009; Koebnick *et al*. 2004;Tucker *et al*. 2000), the intake of dairy products had no effect on the vitamin B_{12} status in this study. One reason could be the low intake of dairy products. Korea belongs to the countries with low milk consumption (Speedy 2003). The National Health and Nutrition Survey reported that the average consumption of milk products of the female population was 71 g per day (KHIDI and MHW 2003). By comparison, the consumption of milk products in Germany is more than 200g per day (DGE 2004)

In our study, most of the subjects consumed dried laver; however, only the vegetarian group showed a positive correlation between laver intake and serum vitamin B_{12} levels. Buddhist vegetarians had a high serum vitamin B_{12} concentration compared to other vegetarians (Herrmann *et al*. 2003; Obeid *et al*. 2002). Due to its high content of active vitamin B_{12}, Korean laver can be recommended for vegetarians as a dietary source of vitamin B_{12} (Miyamoto *et al*. 2009; Kwak *et al*. 2008; Watanabe 2007; Yamada *et al*. 1999). Nevertheless, more studies on its bioavailability from Korean laver in vegetarians are needed.

5 Conclusion

There are many dietary patterns in the world and they all have more or less advantageous and disadvantageous effects on health. A diet providing sufficient energy and nutrients can prevent a nutrient deficiency. An optimal composition of the diet can promote health, reduce the risk of diet related diseases and improve the quality of life. A large number of studies have proved that diets largely based on plant food can best fulfill these functions.

The number of vegetarians in Korea is steadily increasing. For many reasons, they consume a meatless diet and should not be forced to eat meat to improve their nutrient status. Instead, they should be informed about how to avoid nutrient deficiencies and maintain as well as promote their health with a vegetarian diet. For instance, vegetarians can reach an adequate iron supply if they consume a diet high in whole grain, legumes, seeds, and nuts with food preparations that remove or degrade phytic acid and if they concurrently eat vitamin C rich fruits and vegetables.

In Western countries, well-planned vegetarian diets are known to be appropriate for all stages of the life cycle and to have many health benefits. Moreover, there are food based guidelines for Western vegetarians. In contrast, there is no food guideline for vegetarians in Korea. The food culture of Korea is unique and the concerns of Korean vegetarians are different from those of Western vegetarians. For instance, unlike in Western countries, fortified foods and milk are no relevant dietary sources of iron, folate, and vitamin B_{12} for Korean vegetarians. Instead, sea vegetables contribute more to the supply of these nutrients in Korea. Additionally, they provide iodine and omega-3-fatty acids. The development of food guidelines for vegetarians is necessary, because a vegetarian diet has potential beneficial effects on health and the advantages of vegetarian diets can be ensured by an adequate diet composition and food preparation.

Although the nutritional status of Buddhist vegetarians is generally appropriate and comparable or more favorable than that of omnivores, further studies should investigate the fatness of Buddhist vegetarians, the bioavailability of vitamin B_{12} from Korean laver, and the intake of omega-3-fatty acid from plant sources.

6 Summary

The aim of this study was to determine the nutritional status of vegetarian Buddhist nuns who represent the oldest and the most traditional vegetarian group in South Korea and to compare the results with omnivorous women. Dietary intake, BMI, body composition, serum lipids status, and the nutritional status of iron, folate, and vitamin B_{12} were investigated.

A total of 178 female subjects residing in Daegu and Gyeongbuk Province in South Korea voluntarily participated in the study between October 2002 and March 2003. According to the inclusion criteria, 54 vegetarian Buddhist nuns, 31 omnivorous Catholic nuns, and 31 omnivorous college students were enrolled.

The nutrient intakes of Buddhist vegetarians were comparable to those of omnivores, and the intake of some nutrients in vegetarians was even more favorable than in omnivores. The energy intake from food of plant origin in Buddhist vegetarians, omnivorous Catholic nuns and college student was 98%, 95%, and 77%, respectively. The nutrient intakes from plant origin of vegetarian and omnivorous nuns were mostly higher than those of the omnivorous college students. In contrast, the intake of nutrients originating from animal sources among omnivorous students was higher than those of Buddhist vegetarians. The intakes of total calcium and total iron of Buddhist vegetarians were higher than those of omnivorous students, but did not differ from those of omnivorous Catholic nuns.

There was no difference in body height and body fat between the dietary groups, but the vegetarians had a significantly higher body weight, fat free mass, and BMI than both omnivorous groups. The median BMI of vegetarian and omnivorous groups still fell into the normal range. Among vegetarians, body fat was inversely correlated with the duration of vegetarianism, which ranged from 3 to 34 years.

The Buddhist vegetarians had a lower total and HDL cholesterol blood level than both omnivorous groups, and there was no difference between the omnivorous groups. The triglyceride levels of Buddhist vegetarians did not differ from those of omnivorous groups, and the college students had lower levels than the Catholic nuns. There was no significant difference in LDL-cholesterol and LDL/HDL cholesterol ratio between the groups.

The LDL/HDL cholesterol ratio was positively associated with the BMI in the vegetarian group and the percentage of body fat in omnivorous Catholic nuns. Among the omnivorous Catholic nuns, the HDL cholesterol level showed an inverse

correlation with body weight adjusted body fat and body fat percentage. Furthermore, fat free mass, after weight adjustment, correlated positively with HDL cholesterol. Among vegetarians, energy adjusted cholesterol intake had a positive correlation with serum total cholesterol as well as HDL cholesterol concentrations. Total cholesterol and LDL cholesterol had a highly positive correlation with the intake of cholesterol and animal protein.

There was no difference in hemoglobin status among the dietary groups. The serum ferritin and hematocrit levels of vegetarians did not differ from those of omnivorous students with a high intake of animal source foods but a low intake of vitamin C. These levels were lower than those of omnivorous Catholic nuns with a modest consumption of animal source foods and a high intake of vitamin C. In vegetarians, the energy adjusted vitamin C intake showed a positive correlation with both serum ferritin and hemoglobin concentrations.

Although the Buddhist vegetarians in this study had a very low intake of animal source foods, the serum vitamin B_{12} levels of all subjects except one vegetarian and the serum folate levels of all subjects except one omnivorous student fell within normal ranges.

Unlike in Western vegetarian diets, fortified foods and milk play a minor role as dietary sources of iron, folate and vitamin B_{12} in the Korean vegetarian diet. Instead, sea vegetables contribute to the supply of these nutrients. Serum vitamin B_{12} of vegetarians was positively associated with laver intake. Korean laver can be a good source of vitamin B_{12} for vegetarians. Further, an adequate intake of vegetables and fruits was reflected in the good serum folate status.

In conclusion, dietary guidelines for Korean vegetarians based on the Korean food culture should be developed. This is necessary for the following reasons: a growing number of people lives on a vegetarian diet for ethical, health, and ecological reasons. Vegetarian nutrition has potential beneficial effects on health. With adequate diet composition and food preparation, vegetarians can ensure the advantages of a vegetarian diet.

7 Zusammenfassung

Das Ziel dieser Studie war eine Untersuchung des Ernährungszustands von buddhistischen Nonnen in Südkorea, die die älteste und traditionellste Gruppe der Vegetarier repräsentieren. Die Ergebnisse wurden mit Daten von koreanischen Mischköstlern verglichen. Die Untersuchungsparameter waren die Lebensmittel-aufnahme, der BMI, die Körperzusammensetzung, die Serumlipide sowie der Ernährungszustand von Eisen, Folat und Vitamin B_{12}.

Insgesamt nahmen 178 weibliche Probanden, die in der Daegu und Gyeongbuk Provinz Südkoreas leben, freiwillig an der Studie zwischen Oktober 2002 und März 2003 teil. Gemäß der Einschlusskriterien, waren 54 vegetarische buddhistische Nonnen, 31 katholische Nonnen und 31 Studentinnen, die eine Mischkost verzehrten, in die Untersuchung eingebunden.

Die Nährstoffaufnahme der buddhistischen Vegetarier war vergleichbar mit der von Mischköstlern, wobei die Aufnahme der meisten Nährstoffe bei den Vegetariern besser war als bei den Mischköstlern. Die Energieaufnahme der vegetarischen Nonnen aus pflanzlichen Lebensmitteln lag bei 98%, die der katholischen Mischköstler bei 95% und die der studentischen Mischköstler bei 77%. Die Nährstoffaufnahme pflanzlichen Ursprungs war bei den buddhistischen und katholischen Nonnen höher als bei den studentischen Mischköstlern. Im Gegensatz dazu war die Nährstoffaufnahme von tierischen Lebensmitteln bei den Studentinnen höher als bei den buddhistischen Vegetariern. Die Gesamtaufnahme von Calcium und Eisen der buddhistischen Vegetarier war höher als die der studentischen Mischköstler, aber vergleichbar mit der der katholischen Mischköstler.

Es gab keine Unterschiede bezüglich Körpergröße und Körpergewicht zwischen den drei Gruppen, dennoch hatten die Vegetarier ein signifikant höheres Körpergewicht, eine höhere fettfreie Körpermasse und einen höheren BMI (kg/m^2) als beide Mischkostgruppen. Der Median-BMI der vegetarischen Gruppe und der Mischkostgruppen fiel jedoch in den Normbereich. Bei den Vegetariern war der Körperfettgehalt negativ mit der Dauer des Vegetarismus korreliert, die zwischen 3 bis 34 Jahren lag.

Die buddhistischen Vegetarier hatten einen niedrigeren Gesamtcholesterin- und HDL-Cholesterin-Wert als beide Mischkostgruppen, welche sich nicht unterschieden. Die Triglycerid-Werte der buddhistischen Vegetarier unterschieden sich nicht von denen der Mischkostgruppen, wobei die studentischen Mischköstler einen niedrigen

Wert als die katholischen Nonnen hatten. Es gab keine signifikanten Unterschiede bezüglich des LDL-Cholesterins und des LDL/HDL-Cholesterin-Quotienten zwischen den drei Gruppen.

Der LDL/HDL-Quotient war positiv mit dem BMI in der vegetarischen Gruppe und mit dem prozentualen Körperfett der katholischen Nonnen assoziiert. Bei den katholischen Mischköstlern hatte das HDL-Cholesterin eine inverse Korrelation mit dem gewichtsadjustierten Körperfett und dem prozentualen Körperfett. Weiterhin korrelierte die fettfreie Körpermasse nach der Gewichtsadjustierung positiv mit dem HDL-Cholesterin. Bei den Vegetariern war die energieadjustierte Cholesterin-aufnahme positiv mit der Gesamtserum-Cholesterin- und der HDL-Cholesterin-Konzentration korreliert. Das Gesamtcholesterin und LDL-Cholesterin waren beide stark positiv korreliert mit der Aufnahme von Cholesterin und tierischem Protein.

Es gab keine Unterschiede hinsichtlich des Hämoglobinstatus zwischen den drei Gruppen. Die Serum-Ferritin- und Hämatokrit-Werte der Vegetarier unterschieden sich nicht von den Werten der studentischen Mischköstler mit einer hohen Aufnahme tierischer Lebensmittel, aber einer geringen Aufnahme von Vitamin C. Diese Werte waren geringer als die der katholischen Mischköstler mit einer moderaten Aufnahme tierischer Lebensmittel und einer hohen Vitamin-C-Aufnahme. Bei den Vegetariern war die energieadjustierte Vitamin-C-Aufnahme sowohl mit der Serum-Ferritin als auch mit der Hämoglobin-Konzentration positiv korreliert.

Die Serum-Vitamin-B_{12}-Werte aller Probanden, außer einer Vegetarierin und die Serum-Folat-Werte aller Probanden, außer einer studentischen Mischköstlerin, fielen in den Normbereich. Nur bei den Vegetariern waren die Serum-Vitamin B_{12}-Werte positiv mit der Aufnahme von Seetang korreliert. Obwohl die buddhistischen Vegetarier in dieser Studie eine sehr niedrige Aufnahme tierischer Lebensmittel hatten, war die Prävalenz von Eisen-, Vitamin B_{12}- und Folatmangel bei den Vegetariern nicht höher als bei den Mischköstlern mit einer hohen Aufnahme tierischer Lebensmittel.

Im Gegensatz zu westlicher vegetarischer Ernährung spielen angereicherte Lebensmittel und Milch als Quellen für Eisen, Folat und Vitamin B_{12} in Korea eine untergeordnete Rolle. Stattdessen diente Seegemüse als diese Nährstoffquelle. Koreanischer Seetang stellt eine gute Quelle für Vitamin B_{12} für Vegetarier dar. Eine adäquate Aufnahme von Gemüse und Früchten spiegelte sich im guten Serum-Folat-Status wider.

Schlussfolgernd sollten Ernährungsempfehlungen oder Richtlinien für koreanische Vegetarier entwickelt werden, die auf der koreanischen Esskultur basieren. Diese Maßnahme ist aus folgenden Gründen notwendig: Immer mehr Menschen ernähren sich aus ethischen, gesundheitlichen und ökologischen Gründen vegetarisch. Die vegetarische Ernährung hat potentiell nützliche Effekte auf die Gesundheit. Mit einer adäquaten Zusammenstellung und Zubereitung ihrer vegetarischen Kost können die Vegetarier die Vorteile dieser Ernährungsform sichern.

8. Published articles

Short Communication

Body composition and nutrient intake of Buddhist vegetarians

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We described the body composition and nutrient intake of Buddhist vegetarians and compared the data with that of omnivores in South Korea. Vegetarian subjects were 54 Buddhist nuns, who adhered to a vegetarian diet in accordance with Buddhist teachings. We compared these finding with a group of 31 omnivore Catholic nuns who shared a similar lifestyle but different dietary pattern than those of the Buddhist nuns. All subjects completed the estimated three-day dietary record. Body composition was determined by a segmental multi-frequency-bioelectrical impedance analysis method. No height difference between the dietary groups existed but the vegetarians had a significantly higher body weight, fat free mass, body fat and body mass index (BMI, kg/m^2) than the omnivores. The median BMI of both vegetarians and omnivores fell in the normal range (22.6 vs. 20.7 kg/m^2). In vegetarians, body fat was inversely correlated with the duration of vegetarianism (p for trend = 0.043). The long duration group of the vegetarians had lower body fat than the short duration group (12.l vs. 15.0 kg, p = 0.032). The status of the nutrient intake of Korean Buddhist vegetarians was comparable to that of omnivores, and the intake of some nutrients in vegetarians was more favorable than in the omnivores.

Key Words: vegetarian, duration of vegetarianism, body fat, BMI, nutrient intake

INTRODUCTION

Western vegetarians have been widely studied.[1,2] Religious groups (e.g. Seventh Day Adventists) in US-studies[3-5] and nonreligious groups (e.g. health food shop users, members of vegetarian society) in Europe[6-8] have been predominantly investigated. In comparison, the nutritional status of vegetarians in East Asia has not been widely studied.

The Western vegetarian diet differs significantly from the typical Western diet which is characterized by a high intake of meat and total fat, especially saturated fatty acids or cholesterol, and a low intake of vegetables and fiber, vitamin C or folate. This dietary pattern is considered one of the most important dietary risk factors for obesity and other diseases. In contrast, the typical Asian diet is based mostly on grains and plant foods, and is similar to the Asian vegetarian diet. Therefore, the differences in dietary patterns between Asian vegetarians and omnivores are not as prominent as those found between individuals with the typical Western diets and Western vegetarians. In view of this fact, we predict that our study may reveal different results from Western vegetarian studies.

We described the body composition and nutrient intake of Buddhist vegetarians and compared these results with omnivores in South Korea.

The diet of Koreans is primarily based on food from plant origins. According to "The Korean National Health & Nutrition Examination Survey",[9] the average consumption of food from plant sources by Koreans amounts to 80 %. Current official statistics on Korean vegetarians are not available, but the Korean Vegetarian Union[10] has estimated that vegetarians account for less than 1% of the population, with increasing interest in vegetarianism.

Buddhist nuns and monks represent the oldest and the most traditional vegetarian group in Korea. Therefore, the increasing interest in the nutritional aspects of the vegetarian diet is specifically focused on the Buddhist vegetarian diet. They mainly eat "Temple food": originally cooked vegan and occasionally with the addition of dairy products. In general, the Korean Buddhist diet is characterized by avoidance of:[11] 1) food of animal origin, except milk products, 2) five pungent vegetables (O Shin Tschae): garlic (*allium sativum*), welsh onion (*allium fistulosum*), wild garlic (*allium monathum*), garlic chives (*allium tuberosum*), and asant (*ferula asafoetida*), 3) alcohol and 4) high amounts of processed food.

MATERIALS AND METHODS

A total of 178 subjects (97 vegetarians and 81 omnivores) voluntarily participated between October 2002 and March 2003. All subjects were women and residing in Daegu and Gyeongbuk Provinces of South Korea. Vegetarian subjects were Buddhist nuns who adhered to a vegetarian diet based on Buddhist teachings. The omnivore group consisted of 41 Catholic nuns and 40 college students and laboratory technicians. Of these subjects, only Catholic nuns were enrolled for this study because their lifestyle

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was similar and the dietary pattern different from that of the Buddhist nuns.

The inclusion criteria were: 1) apparently healthy, without physician-diagnosed diseases, and no medication intake, 2) no dietary supplement use (e.g. mineral and vitamin supplement or health functional foods) for the last six months 3) The subjects who completed three-day dietary record.

According to these criteria, 54 vegetarian Buddhist nuns aged 21-44 years and 31 omnivores Catholic nuns aged 22-41 years were included. They attended classes, in particular: a 4 year-college course for Buddhist nuns and a vocational training program for Catholic nuns. They belonged to a way of life with communal living in a temple or in a convent.

This study was approved by the Ethics Committee of Justus-Liebig University Giessen in Germany and all participants gave written and informed consent to participate.

Anthropometric and body composition measurements using segmental multi-frequency-bioelectrical impedance analysis (SM-BIA)

Height was measured to the nearest 0.1 cm and body weight to the nearest 0.1 kg using a digital scale integrated BIA. Body mass index (BMI) was calculated as body weight in kilogram divided by the square of height in meters (kg/m²).

Body composition was determined by a segmental multi-frequency-bioelectrical impedance analysis (SM-BIA) method (InBody 3.0, Biospace Co. Ltd, Korea). In contrast to single frequency, whole body measurement, which assumed the body as a single cylinder, SM-BIA assumes the body is five cylinders (arms, legs, and trunk) and measures with an 8-point tactile electrode at frequencies of 5, 25, 250, 500 kHz. Using the multi-frequency analysis, intracellular water and extracellular water currents are measured separately. The precision and accuracy of the device were validated by other studies.[12-14] After overnight fasting, the body compositions of the subjects were measured as the subject stood on the foot electrodes (left, right anterior and posterior) and grasping the hand electrodes (left, right thumb and palm). Height and age were entered in the BIA software, while body weight, body mass index (BMI, kg/m^2), fat free mass and body fat were measured and calculated by the BIA software.

Dietary Assessment

The subjects were informed about portion sizes with food models and photographs of food[15] and were instructed to complete the estimated dietary record using household measures. The estimated amount and the main ingredients of foods eaten were recorded by participants themselves for three consecutive days. In addition, the nuns in charge of cooking were asked to document the recipes of the vegetarian dishes. Based on this information (food records and recipes of the vegetarian meals), standardized recipes[16] were adapted and entered into the nutritional program. Can-Pro 2.0 (Computer Aided Nutritional Analysis Program version 2.0, The Korean Nutrition Society, 2002, Seoul) was used for analysis of dietary data.

Statistical Analysis

Statistical analysis was performed using SPSS for Windows (version 12.0.1). Initially after the normal distribution test (Kolmogorov-Smirnov test and Shapiro-Wilk test), normally distributed data were tested by Student's *t* test, whereas non-normally distributed data were analyzed by the Mann-Whitney U test and Spearman's rank-order correlation coefficient. The Jonckheere-Terpstra test assessed trend analysis for duration of vegetarianism and body fat. A p value of < 0.05 was considered statistically significant.

RESULTS

The characteristic of the study population is presented in Table 1. The mean age of the vegetarian and omnivore groups was 30.4 and 31.4 years, respectively. The duration of vegetarianism ranged from 3 to 34 years (median [interquartile range], 6.5 [4-13]). There was no difference in terms of height between the dietary groups, but the vegetarians had a significantly higher body weight, fat free mass, body fat and BMI compared with the omnivores. The median BMI of both vegetarians and omnivores fell in the normal range[17] (22.6 vs. 20.7 kg/m^2).

BMI was classified in accordance with the WHO-Criteria.[17] As shown in Figure 1, 80% of vegetarians and 74% of omnivores were in the normal range (18.5-24.9 kg/m^2). The prevalence of underweight (BMI < 18.5 kg/m^2) cases in the omnivore group was higher than in the vegetarian group, while the vegetarians showed tendencies of pre-obesity (25.0-29.9 kg/m^2). None of the omnivores and one vegetarian fell into the classification of grade I obesity (30.0-34.9 kg/m^2).

In vegetarians, body fat was correlated not with age (p = 0.854), but with duration of vegetarianism, although duration of vegetarianism had a positive correlation with age (spearman's coefficient $\rho = 0.326$, $p = 0.016$).

Table 1. Characteristic of the study population

	Vegetarians (n = 54)		Omnivores (n = 31)		*p value*
Age (y)	30.4	(5.98)	31.4	(4.08)	0.383^t
Duration of vegetarianism (y)	6.5	[4.0-13.0]	-		
Height (cm)	160.0	[158.8-164.0]	160.0	[156.0-162.0]	0.170
Weight (kg)	57.6	[54.5-61.9]	53.5	[48.5-60.8]	0.016
Fat free mass (kg)	44.5	(3.75)	41.8	(5.10)	0.013^t
Body fat (kg)	13.8	[10.8-16.4]	11.7	[8.5-15.3]	0.037
BMI (kg/m²)	22.6	[20.5-24.1]	20.7	[18.9-22.2]	0.010

Normally and non-normally distributed data are presented as mean (SD) and median [1. - 3. inter-quartile], respectively. ^{t} *t* test, No superscript Mann-Whitney U test.

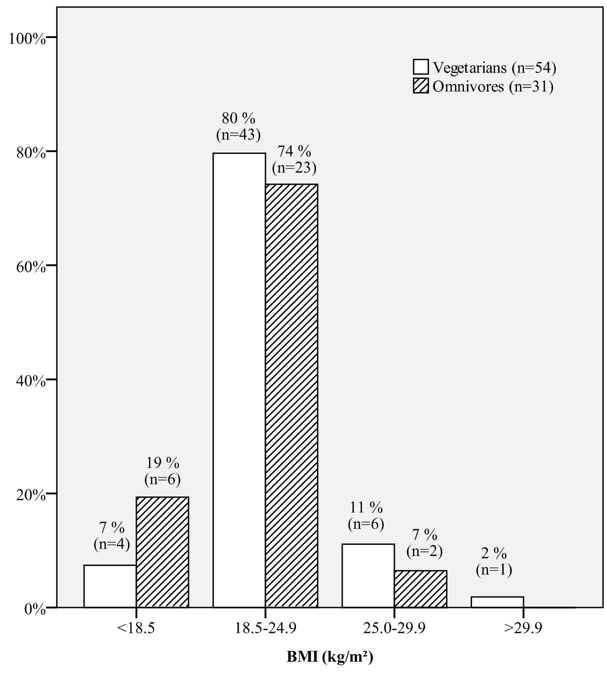

Figure 1. BMI-Classification according to WHO-Criteria (BMI in kg/m²)

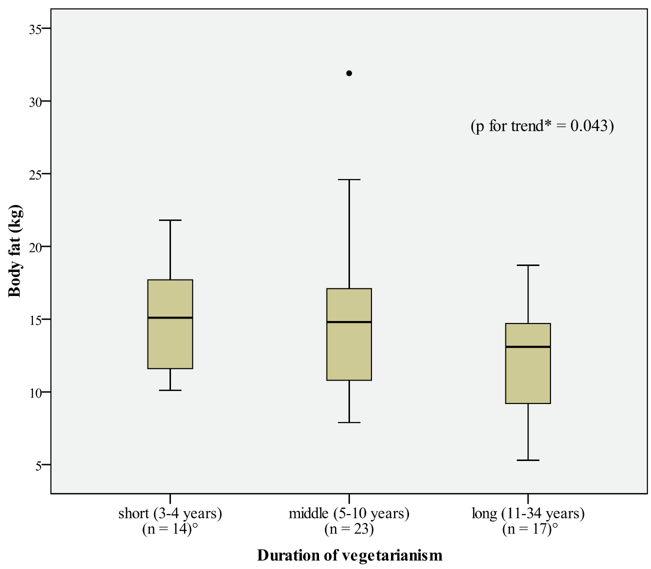

Figure 2. Body fat (kg) of vegetarians by the duration of vegetarianism. *Jonckheere-Terpstra test, °*t* test ($p = 0.032$)

According to the length of adherence to the vegetarian diet, the vegetarians were divided into three subgroups: 3-4 years as short (n = 14), 5-10 years as middle (n = 23), and 11-34 years as long (n = 17). The body fat of these groups is depicted in Figure 2. The Jonckheere-Terpstra test showed that the body fat of vegetarians tended to decrease with the duration of vegetarianism ($p = 0.043$). In addition, the long-term vegetarian group had a lower body fat than the short-term group (12.1 vs. 15.0 kg, *t* test, $p = 0.032$). But there was no significant difference in BMI, body weight, and fat free mass between the short- and long-term groups.

Nutrient intake from the three-day dietary records is presented in Table 2. Intake of total energy, energy from protein, total protein and total fat did not differ between the dietary groups. The vegetarians consumed more energy from fat. On the other hand, the omnivore group had higher intake of both carbohydrates and energy from carbohydrates. Nevertheless, the vegetarians ingested more crude fiber. As expected, the omnivores had significant higher intakes of all nutrients from animal origin (e.g. animal protein, animal fat, cholesterol, animal calcium, animal iron) than the vegetarians. But the intake of some nutrients from plant origin, such as plant fat, vitamin E and plant iron did not differ between the dietary groups. In addition, there were no differences in terms of intake of: vitamin B_1, vitamin B_2, total calcium and total iron. The vegetarians had a significantly higher intake of vita-

Table 2. Nutrient intake from three-day dietary records

	Vegetarians (n = 54)		Omnivores (n = 31)		*p value*
Energy (kcal)	1756.2	[1371.2-2020.7]	1866.7	[1627.7-2103.0]	0.075
Protein, in % kcal	11.7	[11.1-12.8]	11.5	[10.7-15.7]	0.371
Carbohydrates, in % kcal	72.8	[67.5-75.8]	75.3	[72.5-77.4]	0.047
Fat, in % kcal	15.6	[12.3-19.8]	13.0	[12.0-15.2]	0.049
Total protein (g)	51.3	[39.6-64.0]	56.4	[46.3-61.7]	0.165
plant protein (g)	48.1	(12.47)	42.6	(7.88)	0.015^{t}
animal protein (g)	2.5	[0.3-5.2]	11.3	[9.9-14.6]	0.000
Carbohydrates (g)	312.9	[252.6-371.9]	355.5	[306.4-383.7]	0.014
Crude fiber (g)	9.3	[7.1-11.4]	7.6	[6.6-8.9]	0.011
Total fat (g)	30.2	[21.9-40.3]	28.7	[24.2-36.5]	0.906
plant fat (g)	27.0	[19.7-36.1]	23.4	[18.4-27.5]	0.089
animal fat (g)	2.3	[0.1-6.8]	5.2	[3.4-8.8]	0.004
Cholesterol (mg)	10.8	[3.4-29.8]	70.0	[56.7-117.4]	0.000
Vitamin A (mg RE*)	0.63	[0.48-0.84]	0.55	[0.46-0.64]	0.018
ß-carotene (mg)	3.61	[2.83-4.76]	3.02	[2.67-3.65]	0.030
Vitamin E (α-TE§)	12.4	(4.61)	11.1	(2.92)	0.094^{t}
Niacin (mg)	13.9	(3.84)	11.8	(2.01)	0.001^{t}
Vitamin B_1 (mg)	1.1	(0.34)	1.2	(0.25)	0.138^{t}
Vitamin B_2 (mg)	0.9	(0.27)	0.8	(0.15)	0.099^{t}
Vitamin B_6 (mg)	2.1	(0.53)	1.9	(0.33)	0.005^{t}
Total calcium (mg)	524.1	[426.6-695.0]	519.0	[457.2-595.1]	0.956
plant calcium (mg)	449.8	(130.62)	361.2	(70.44)	0.000^{t}
animal calcium (mg)	69.8	[8.3-149.9]	153.6	[140.9-205.9]	0.000
Total iron (mg)	14.1	[10.9-17.3]	15.2	[12.4-21.6]	0.059
plant iron (mg)	13.9	[10.7-17.1]	14.0	[10.7-20.3]	0.338
animal iron (mg)	0.1	[0.0-0.3]	2.0	[0.8-1.3]	0.000

Normally and non-normally distributed data are presented as mean (SD) and median [1. - 3. inter-quartile], respectively. ^{t} *t* test, No superscript Mann-Whitney U test, *⁾RE Retinol Equivalent, §⁾α-TE α-Tocopherol Equivalent.

min A, ß-carotene, niacin, vitamin B_6 and plant calcium than the omnivores.

The median percentage of animal protein intake from total protein was 21.6 % in omnivores and 3.9 % in vegetarians. The median percent of energy intake from food of animal origin was 2.1 % in vegetarians and 5.0 % in omnivores.

DISCUSSION

Unlike many of the other Western vegetarian studies, the Buddhist vegetarians in this study had higher body fat and BMI, as well as higher fat free mass than the omnivore group. But this was consistent with other Korean Buddhist vegetarian studies.[18,19] Korean Seventh Day Adventist and Chinese vegetarian studies often showed no difference in BMI between vegetarians and omnivores, especially in age matched female groups.[20-28] On the other hand, the vegetarians, especially the vegans in the Western studies have significantly lower BMI than the omnivores.[29,30] This difference is obvious, when the omnivore group is obese. Moreover, Korean omnivores were found with a much lower BMI than Western omnivores. In spite of a tendency for overweight in Buddhist vegetarians, the median BMI of the vegetarians (22.6 kg/m²) was still within the normal range and comparable with that of European vegetarians of the similar age, and even lower than that of US vegetarians.[29,31,32]

Interestingly, in Buddhist vegetarians body fat tended to decrease with the duration of vegetarianism. The long-term vegetarian group had lower body fat than the short-term group. But fat free mass and BMI was not correlated with length of adherence to the vegetarian diet. Similarly, the German Vegan Study[33] showed that there was no significant difference in the BMI between strict and moderate vegans, however, the strict vegans had a significant lower body fat mass than the moderate vegans.

Dietary patterns of vegetarians are so diverse that it is not easy to categorize the type of vegetarians according to this term alone.[1,34,35] More than twenty years ago, Korean Buddhist nuns and monks were vegans.[36,37] The modern Korean Buddhist nuns and monks still follow a vegan diet, however, occasionally they consume milk, yoghurt, cheese or breads, cookies and cakes which often contain eggs or butter.[38-41] These Western snacks are the main source of cholesterol and animal fat in the Buddhist vegetarian diet. The type of snacks and the frequency of their consumption varied, because most of them were irregularly donated by Buddhist followers. Therefore, in our study, it was difficult to estimate their usual intake of cholesterol or animal fat. Total energy intake was also strongly influenced by the consumption of these snacks, containing relatively high amounts of fat and sugar, because “Temple Food”, according to the Korean traditional cooking, consists mainly of a low fat and low sugar diet.[38,41] Korea belongs to the group of countries with low milk consumption.[42] The Buddhist nuns can be defined as lacto-vegetarians, however the amount of foods from animal sources they consume is comparable with that of Western “moderate vegans”.[33]

The intake of carbohydrates and fat makes the difference in the nutrient intake between the Western and the Korean diet; Korean vegetarians, as well as omnivores, also have a higher carbohydrate intake and a lower fat intake compared with other Asian vegetarians.[18,25,28,43,44]

Rice and other grains are the basis of the high carbohydrate diet in Korea. Although the consumption of grain products has been declining continuously, the daily average intake of grain products was 306 g and it accounted for 58 % of the total energy intake.[9] Therefore, it is not rare in Korea to find no difference in total carbohydrates intake between vegetarians and omnivores.[21,22,45] In our study, omnivores consumed even more carbohydrates than vegetarians. This was due to high consumption of fruits in the study period. But there were no differences in terms of intake of grain products and sugar products between the dietary groups. Nevertheless, vegetarians consume more crude fiber than omnivores because of their higher consumption of vegetables with low energy density. Both the vegetarian diet and the traditional Asian diet primarily consist of vegetables and grains. Therefore, there are no significant differences in the intake of foods of plant origin such as carbohydrates, vitamin C, vitamin E and PUFA between the vegetarians and the omnivores in this study, as well as in other Asian vegetarian studies.[21,22,26,46]

During the rapid economic development in low-income countries, a dramatic transition and adaptation to the Western dietary habits ("westernization") occurred. Like in other Asian countries, the dietary practices in Korea have rapidly changed; the consumption of animal source food has been increasing. At the same time, efforts at the regional and governmental level not only to keep but also to develop a traditional Korean diet have been established. Therefore, the dietary shift to "westernization" with high fat intake has not changed the Korean diet as drastically as in other Asian countries.[47] The low fat content of Buddhist diets is integral to their cooking method based on the typical Korean cooking style.[38] In a previous study on the Buddhist nuns in the same Buddhist temple in 1981[19] and in 1997,[18] the percentage of energy intake from fat was only 4.9 % and 11.6 %, respectively. As they rarely eat-out or consume processed food, the Buddhist vegetarians maintained a relatively low energy intake from fat. A Korean Seventh Day Adventist (SDA) study showed the nutrient intake of SDA-college students who ate accordingly to a well-planned lacto-ovo-vegetarian diet based on the traditional cooking method. The distribution of energy intake from macronutrients was described as 70% carbohydrates, 16 % protein and 14 % fat.[48] These results are similar to that of the vegetarians and omnivores in our study.

The dietary cholesterol intake of Buddhist vegetarians came mainly from different types of breads, custard cream puffs, castella (sponge cake), muffins, doughnuts, cheese and milk. The mean cholesterol intake was lower than that of Western female vegans.[49-51]

Compared with carbohydrate and fat intake, the difference in protein intake between the Asian and Western population is not large; the protein intake of Buddhist vegetarians was comparable with other Asian vegetarians[18,21,27,28] and Western vegans.[49-51]

Dairy products are a rich source of calcium and are readily available. Achieving adequate calcium intake without supplements depends on the consumption of dairy products. The German Nutrition Survey[52] showed that dairy products accounted for about 50 % of the calcium intake, and bottled water ranked second with 15 %. In the US, dairy products provided about 73 % of the dietary calcium, whereas calcium from vegetables accounted for only 7 %.[53] In contrast, according to the report on the National Health and Nutrition Survey[9] in Korea, foods from animal sources contributed to 41.8% of total calcium intake (dairy products 18.2 %, fish group 20.2 %). Plant foods provided the remaining 58.2 %. Vegetables were the leading source of calcium (27.4 %). In our study the omnivore group had consumed 67.3 % of total calcium and 93.5 % of total iron from plant sources. While plant were the source for 90.4 % of total calcium and 98.9% of total iron for vegetarians. Calcium and iron have showed the highest deficiencies in the Korean diet. Many studies showed that vegetarians have a relatively higher intake of calcium and iron, but this may not indicate optimal nutritional status. Bioavailability of calcium and iron of plant origin are more sensitive to inhibitory and enhanced effects by other components (e.g. vitamin C, phytate, caffeine, protein etc). Therefore, vegetarians should be more concerned about meal composition and bioavailability of such nutrients.

CONCLUSION

Diets in Asian countries are currently undergoing nutrition transition. Vegetarianism protects the body from the adverse effects of the 'westernization' of diets. Unlike most Western vegetarians documented, Buddhist vegetarians in this study had higher fat free mass, body fat and BMI than omnivores. Body fat was inversely correlated with duration of vegetarianism for the vegetarians. The nutrition status of Korean Buddhist vegetarians was comparable to that of omnivores, and the intake of some nutrients in vegetarians was even more favorable than that of omnivores.

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AUTHOR DISCLOSURES

The Authors declare that they have no conflict of interest.

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Short Communication

Body composition and nutrient intake of Buddhist vegetarians

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信奉佛教的素食者之體組成及營養素攝取

我們說明南韓信奉佛教的素食者之體組成及營養素攝取，並與雜食者的數據作比較。有 54 名佛教尼姑的素食者為研究對象，她們依佛教的教條而吃素。另外一組 31 名雜食的天主教修女做比較對象，她們與佛教尼姑有相似的生活型態，卻有不同的飲食模式。所有的受試者完成 3 天的飲食紀錄。以部份多頻率生物電阻法評估體組成。兩組間沒有身高的差異，但是素食者比起雜食者，有顯著較高的體重、非脂肪重、體脂肪及身體質量指數(BMI, kg/m^2)。素食者及雜食者的 BMI 中位數均屬正常範圍 (22.6 及 20.7 kg/m^2)。在素食者，體脂肪與吃素的持續時間為負相關(p for trend = 0.043)。長期的吃素者比起吃素時間短的受試者有較低的體脂肪(12.1 vs. 15.0 kg, p=0.032)。韓國佛教徒的吃素者之營養素攝取狀況與雜食者是可相比的，且某些營養素的攝取比起雜食者更佳。

關鍵字：素食者、吃素持續時間、體脂肪、身體質量指數、營養素攝取

Short Communication

The nutritional status of iron, folate, and vitamin B-12 of Buddhist vegetarians

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Nutritional status of iron, folate, and vitamin B-12 in vegetarians were assessed and compared with those of non-vegetarians in Korea. The vegetarian subjects were 54 Buddhist nuns who ate no animal source food except for dairy products. The non-vegetarians were divided into two groups: 31 Catholic nuns and 31 female college students. Three-day dietary records were completed, and the blood samples were collected for analyzing a complete blood count, and serum levels of ferritin, folate, and vitamin B-12. There was no difference in hemoglobin among the diet groups. The serum ferritin and hematocrit levels of vegetarians did not differ from that of non-vegetarian students with a high intake of animal source food but low intake of vitamin C, and the levels were lower than that of non-vegetarian Catholic nuns with a modest consumption of animal source food and a high intake of vitamin C. The serum vitamin B-12 levels of all subjects except one vegetarian and the serum folate levels of all subjects except one non-vegetarian student fell within a normal range. In vegetarians, there was a positive correlation between the vitamin C intake and serum ferritin levels as well as between the laver intake and serum vitamin B-12 levels. In order to achieve an optimal iron status, both an adequate amount of iron intake and its bioavailability should be considered. Sufficient intake of vegetables and fruits was reflected in adequate serum folate status. Korean laver can be a good source of vitamin B-12 for vegetarians.

Key Words: iron, folate, vitamin B-12, Buddhist vegetarians, vegetarian diet

INTRODUCTION

Iron, folate, and vitamin B-12 are the crucial nutrients involved in active erythropoiesis, and their deficiencies result in decreased erythrocyte production, consequently leading to anemia.[1] Of these, iron deficiency is the most prevalent nutrient deficiency in both developing and industrialized countries, despite abundant iron supplies on earth.[2] Infant, children, and women of childbearing age, especially during pregnancy are mainly affected due to their high iron requirement.[3] Additionally, those who consume little animal source food or have a diet with low iron bioavailability can eventually develop iron deficiency.[4] The morphological characteristics of iron deficiency anemia are generally hypochromic and microcytic cells due to insufficient transport of hemoglobin to erythrocytes.[1] In contrast, the anemia caused by folate or vitamin B-12 deficiency is often macrocytic due to immature erythrocytes resulting from defective DNA synthesis.[5] A deficiency in either nutrient deactivates the methylation of homocysteine to methionine, which results in an elevated homocysteine level.[6] Moreover, a lack of vitamin B-12-dependent methionine synthase, which demethylates methyl tetrahydrofolate (THF), can lead to functional deficiency.[7] Because the hematological change in deficiency of either vitamin is indistinguishable and because these vitamins are metabolically interrelated, both should be assessed in order to differentiate between the two deficiencies.[8] In contrast to metabolic interaction between folate and vitamin B-12, their dietary sources are completely different. Whereas folate is mostly found in plants such as legumes, vegetables, and fruits,[9] vitamin B-12 is known to be predominantly present in animal tissue and generally absent in plants, with the exception of some seaweeds.[10-12] Therefore, vegetarians who consume less animal source food are considered a risk group for vitamin B-12 deficiency; although vitamin B-12 is seldom exhausted due to the enterohepatic circulation, and the clinical manifestation of vitamin B-12 deficiency rarely occurs, even without intake of vitamin B-12 for many years.[12]

Buddhist nuns and monks are the oldest vegetarian group in Korea. In accordance with Buddhist precepts, they have basically adhered to a vegan diet and have only occasionally consumed dairy products.[13,14] Therefore, they can be classified as lacto-vegetarians. The amount of consumed dairy products, however, is much lower than those of Western lacto-vegetarians; their intake of dairy products was comparable to "moderate" vegans.[13] With an increasing interest in vegetarian nutrition in Korea, the Buddhist vegetarian diet has been getting more attention. Nevertheless, the nutritional status of iron, folate, and vitamin B-12 in Buddhist vegetarians has not been investigated.

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Thus, we assessed the dietary intake as well as the hematological and biochemical status of iron, folate, and vitamin B-12 in Buddhist vegetarian nuns and compared them to those of non-vegetarian women in Korea. Additionally, correlations between dietary intake and blood parameters were determined.

MATERIALS AND METHODS

As described in more detail in a previous article,[13] the eligible vegetarian subjects were 54 Buddhist nuns between 21 and 44 years of age who had adhered to a vegetarian diet for more than 3 years. Except for the modest consumption of dairy products, they ate no animal source food such as meat, poultry, fish, or eggs. The non-vegetarians were divided into two groups. One consisted of 31 Catholic nuns between 21 and 41 years of age, whose dietary pattern is a plant-based diet with moderate consumption of animal source food. The other non-vegetarian group comprised 31 female college students between 18 and 31 years of age, who had a high intake of animal source food.

The participants included were those who 1) had regular menstrual cycles, 2) took neither dietary supplement nor medication for the last six months, 3) were apparently healthy, and had no physician-diagnosed disease (especially inflammatory disease).

This study was approved by the Ethics Committee of the Justus Liebig University in Giessen, Germany, and all participants were volunteers who had given written, informed consent to participate in the study.

Dietary assessment

All participants were asked to record food intake using household measures for three consecutive days before blood collection and were informed about portion size with food models and photographs.[15] In addition to the estimated amount of food intake, the main ingredients in meals were recorded, and we asked the nuns in charge of cooking to provide the vegetarian meal recipes. Based on this information, the standardized recipes[16] were modified and entered into the nutritional program. Can-Pro 2.0 (Computer Aided Nutritional Analysis Program version 2.0, The Korean Nutrition Society, 2002, Seoul) was used for analysis of dietary data.

Hematological and biochemical indicators

After overnight fasting, a venous blood sample was obtained from all participants. A complete blood cell count was determined by an automated hematology analyzer SE-9000 (TOA Medical Electronics, Kobe, Japan). Serum concentrations of ferritin, folate, and vitamin B-12 were measured by an Electrochemiluminescence Immunoassay (ECLIA), using commercial kits (Elecsys Ferritin, Folate, vitamin B-12 reagent kit, Roche Diagnostics, Mannheim, Germany) on the Elecsys 2010 analyzers (Roche Diagnostics, Mannheim, Germany).

WHO criteria for anemia were used for the reference value:[2] hemoglobin level <120 g/L and hematocrit <0.36. A serum ferritin level below 150 µg/mL is regarded to reflect depleted iron stores.[2] A mean corpuscular volume level below 80 fL is considered microcytosis, and over 100 fL is considered macrocytosis.[17] According to suggestions from WHO Technical Consultation on folate and vitamin B-12 deficiencies,[18] the cut-off value for defining deficiencies based on metabolic indicators was set at <10 nmol/mL for serum folate and at <150 pmol/mL for serum vitamin B-12.

Statistical Analysis

Statistical analysis was performed using SPSS for Windows (version 17, Chicago, IL, USA). For group comparison, one-way ANOVA test was used, when the residuals were normally distributed (Kolmogorov-Smirnov test and Shapiro-Wilk test) and the variances equal (Levene's test). If a significant difference between the groups existed, a post hoc test (Scheffe) was followed for a multiple comparisons procedure that examined further differences between the groups. When the assumptions of ANOVA were not met, the Kruskal-Wallis test was performed. As a post hoc test, Mann-Whitney U test for pairwise comparison was used with Bonferroni's correction. By Pearson chi-square test, we determined whether the frequency of cases beyond the cut-off values were different among diet groups. Fisher's exact test was used when the expected value was less than 5. After the normal distribution tests, normally distributed data were assessed by Pearson correlation and non-normally distributed data by Spearman rank correlation coefficient. A p value <0.05 was considered statistically significant.

RESULTS

The dietary intake related to the status of iron, folate and vitamin B-12 in the study population is summarized in Table 1. Except for energy intake, the differences in nutrient intakes among three groups were noticeable. As expected, the vegetarian group had the highest intake of energy from plant sources, crude fiber, and folate and the lowest intake of energy from animal sources, animal source protein and iron. The non-vegetarian student group had the highest consumption of animal source foods; however, they had the lowest intake of total iron, folate, vitamin C, and crude fiber. The overall dietary pattern of the non-vegetarian Catholic nuns was similar to that of Buddhist vegetarians; however, they consumed, besides dairy products, modest amounts of animal source food such as meat, poultry, eggs, and seafood. Therefore their protein and iron intake from animal sources was higher than that of vegetarians but lower than that of non-vegetarian students. Additionally, they had the highest vitamin C intake due to high consumption of fruits during the research period.

The three major food groups that are sources of iron amounted to 77-78% of total iron intake in all diet groups. These are grains, vegetables including sea vegetables, and legumes in Buddhist vegetarians and non-vegetarian Catholic nuns. The non-vegetarian students had iron intake from not only grains and vegetables, but also from animal source foods, which accounted for 31% of total iron intake. The main dietary sources of folate in vegetarians were vegetables including sea vegetables and other groups, especially spices (78%). The non-vegetarian Catholic nuns had folate intake mostly from vegetables and legumes (75%). The non-vegetarian students consumed dietary folate, not only in vegetables, but also in

Table 1. Dietary intake of selected nutrients

	Buddhist vegetarians (n=54)	Omnivores		*p*-value
		Catholic nuns (n=31)	College students (n=31)	
Energy (kcal)	1756 (1371-2021)	1867 (1628- 2103)	1753 (1100-2285)	n.s‡
Protein (g)	52^{a} (13.3)	56^{a} (9.39)	66^{b} (12.5)	<0.001†
Total iron (mg)	14.1^{a} (10.9-17.3)	15.2^{a} (12.4-21.6)	10.0^{c} (8.9-11.9)	<0.001‡
Animal source iron (mg)	0.1^{a} (0.0-0.2)	1.0^{b} (0.8-1.3)	3.2^{c} (2.6-4.0)	<0.001‡
Plant source iron (mg)	14.1^{a} (10.7-17.1)	14.0^{a} (10.7-20.3)	6.8^{b} (5.2-8.3)	<0.001‡
Folate (µg)	340^{a} (296-430)	267^{b} (241-347)	177^{c} (152-219)	<0.001‡
Vitamin C (mg)	145^{a} (111-211)	197^{b} (141-286)	79.2^{c} (57.9-102.1)	<0.001‡
Crude fiber (g)	9.3^{a} (7.0-11.4)	7.6^{b} (6.6-8.9)	4.3^{c} (4.0-4.9)	<0.001‡
Energy from animal source food (%)	2.0^{a} (0.1-5.3)	5.0^{b} (3.7-6.8)	22.7^{c} (17.9-28.8)	<0.001‡
Animal source protein in total protein (%)	3.9^{a} (0.6-11.5)	21.7^{b} (17.4-27.3)	57.8^{c} (52.2-65.1)	<0.001‡
Animal source iron in total iron (%)	1.1^{a} (0.3-2.0)	6.5^{b} (4.1-9.4)	32.3^{c} (24.8-39.9)	<0.001‡
Laver (g)	1.3^{ab} (0.5-2.4)	1.3^{b} (1.0-2.0)	0.7^{a} (0.4-1.3)	0.005‡
Dairy product (g)	21.7 (5.0-67.1)	37.5 (32.0-115.0)	66.7 (0.0-156.7)	n.s‡

†One-way ANOVA, ‡Kruskal-Wallis test.
The data are presented as mean (SD) using one-way ANOVA and as median (1. -3. interquartile) using Kruskal-Wallis test. Means or medians with different superscript letter are significantly different between the groups after post hoc test (significant level: Scheffe 0.05, Bonferroni's correction 0.017). Means or medians with same superscript letter are not significantly different between the groups after post hoc test.
n.s not significant, p>0.05.

Table 2. Hematological and biochemical indicators of iron, folate, and vitamin B_{12}

	Buddhist vegetarians (n=54)	Omnivores		*p*-value
		Catholic nuns (n=31)	College students (n=31)	
Hemoglobin (g/L)	129 (90)	131 (95)	129 (93)	n.s†
Hematocrit	0.37^{a} (0.24)	0.39^{b} (0.24)	0.38^{a} (0.23)	<0.001†
Serum ferritin (µg/mL)	206^{a} (138-328)	373^{b} (243-574)	239^{ab} (165-471)	0.001‡
Serum folate (nmol/mL)	22.9^{a} (18.6-29.5)	19.7^{a} (17.9-24.9)	15.6^{b} (11.3-17.9)	< 0.001‡
Serum vitamin B_{12} (pmol/mL)	360^{a} (287-444)	527^{b} (422-638)	488^{b} (425-667)	< 0.001‡
Mean corpuscular volume (fL)	91.1^{a} (88.9-92.8)	94.4^{b} (92.5-96.9)	91.8^{a} (86.9-93.1)	< 0.001‡
Beyond the cutoff values (%)				
Hemoglobin <120 g/L (%)	22.2	6.5	12.9	n.s ¶
HCT <0.36	29.6	6.5	19.4	0.039§
Serum ferritin <150 µg/mL (%)	27.8	6.5	19.4	n.s§
Serum folate <10 nmol/mL (%)	0	0	3.2	n.s ¶
Serum vitamin B-12 <150 pmol/mL (%)	1.9	0	0	n.s ¶
MCV <80 fL(%)	1.9	3.2	3.2	n.s ¶
MCV >100 fL(%)	0	3.2	0	n.s ¶

†One-way ANOVA, ‡ Kruskal-Wallis test, §Pearson's chi-square test, ¶Fisher's exact test.
The data are presented as mean (SD) using one-way ANOVA and as median (1. -3. interquartile] using Kruskal-Wallis test. Means or medians with different superscript letter are significantly different between the groups after post hoc test (significant level: Scheffe 0.05, Bonferroni's correction 0.017). Means or medians with same superscript letter are not significantly different between the groups after post hoc test.
n.s not significant, p>0.05.

various food groups distributed relatively evenly. Of these, 11% of folate source was animal source food, and 15% was from other groups such as potatoes, nuts, and beverages, but little from spices.

Vitamin B-12 intake in our study was not directly calculated due to a lack of Korean national food data on vitamin B-12. Therefore, to assess the vitamin B-12 intake of vegetarians, the amount of dairy product and laver intake was considered (Table 1). The Buddhist vegetarians consumed almost exclusively plant food except for some dairy products. Thus, the dietary source of vitamin B-12 from animal foods in our vegetarians was exclusively dairy products. Additionally, Korean laver (*Porphyra tenera*), the most commonly consumed in Korea, is known to contain active vitamin B-12 and is regarded as a plant source of vitamin B-12.[19-21] There was no difference in laver intake between Buddhist vegetarians and non-vegetarian Catholic nuns, but the non-vegetarian students had the lowest intake of laver. The range of dairy product intake in all diet groups was very wide. Hence, even though the non- vegetarian students had the highest median value of dairy product intake, there was no significant difference in the intake of dairy products between groups, except between Buddhist vegetarians and non-vegetarian Catholic nuns.

The descriptive statistics of blood parameters and the frequency of cases beyond the cut-off values (%) are shown in Table 2. The means or medians of all blood parameters in all diet groups fell within the normal reference ranges. There was no significant difference in hemoglobin level between diet groups. 22.2% of vegetarians had a hemoglobin level between 109-119 g/L. The non-vegetarian Catholic nuns had the highest median of hematocrit and serum ferritin concentrations, whereas there was no difference in levels of hematocrit and serum ferritin between Buddhist vegetarians and non-vegetarian students.

The non-vegetarian students had the lowest and the vegetarian group the highest level of serum folate. None of vegetarians or Catholic nuns and only one student was folate deficient. The vegetarian group had the lowest serum vitamin B-12 level, but only one vegetarian had a level below 150 pmol/mL. There was no significant difference between the non-vegetarian groups and none of the non-vegetarians were deficient.

The non-vegetarian Catholic nuns had the highest mean corpuscular volume (MCV), whereas there was no significant difference between Buddhist vegetarians and omnivorous students. One subject from each group had microcytosis, and one Catholic nun had macrocytosis.

Using chi-square test and Fisher's exact test, we determined whether there are differences in the frequencies of cases beyond the cut-off values among the diet groups. Except for hematocrit (p=0.039), the different diets did not lead to statistical differences.

Except for a negative correlation between serum folate concentration and age in vegetarians (r=-0.303, p=0.026), blood variables were correlated with neither age, in all diet groups, nor duration of vegetarianism in vegetarians. Blood variables and nutrient intake are well correlated if the values of all subjects without subgroups are analyzed (Table3). Serum ferritin has a positive correlation with intake of animal protein (r=0.214, p=0.021) and animal source iron (r=0.213, p=0.022). Serum folate concentrations had a strong positive correlation with nutrient intake from plant sources such as folate (r=0.417, p<0.001), vitamin C (r=0.397, p<0.001), and plant protein (r=0.395, p<0.001) and a negative correlation with nutrient intake from animal sources such as animal protein (r=-0.520, p<0.001) and animal source iron (r=-0.517, p<0.001). In contrast, serum vitamin B_{12} was strongly positively correlated with animal protein (r=0.424, p<0.001) and animal source iron (r=0.414, p<0.001) and negatively correlated with intake of plant protein (r=-0.383, p<0.001) and folate intake (r=-0.222, p=0.016).

Serum ferritin concentration in vegetarians was positively correlated with vitamin C intake (r=0.315, p=0.020) and negatively correlated with energy intake (%) from total protein (r=0.274, p=0.045). In non- vegetarian Catholic nuns, serum ferritin concentration showed a strong negative correlation with nutrient intake from plant sources such as plant iron (r=-0.601, p<0.001), plant protein (r=-0.539, p=0.002), and carbohydrates (r=-0.603, p=0.000) and a positive correlation with energy intake from animal source food (r=0.407, p=0.023). Hemoglobin concentration in non- vegetarian Catholic nuns was negatively correlated with plant iron (r=-0,373, p=0.039) but not correlated with animal source iron. Conversely, in the student group, hemoglobin concentration was only positively correlated with animal source iron intake (r=0.369, p=0.041), and there was no correlation between serum ferritin concentration and nutrient intake.

No correlation between serum folate concentration and nutrient intake was found in either vegetarians or non-vegetarian Catholic nuns. However, serum folate in non-vegetarian students was positively associated with vitamin C intake (r=0.385, p=0.032) and negatively associated with energy intake (%) from animal fat (r=-0.403, p=0.025).

Only in vegetarians were serum vitamin B_{12} positively associated with laver intake (r=0.341, p=0.012). No asso-

Table 3. Correlation between blood variables and dietary intake

	All subjects	Buddhist vegetarians	Non- vegetarian	
			Catholic nuns	College students
Serum ferritin	Animal protein intake (+) Animal iron intake (+)	Vitamin C intake (+) Energy intake(%) from total protein (-)	Energy intake (%) from animal sources food (+) Plant iron intake (-) Plant protein intake (-) Carbohydrate intake (-)	
Hemoglobin			Plant iron intake (-)	Animal iron intake (+)
Serum folate	Folate intake (+) Vitamin C intake(+) Plant protein intake (+) Animal protein intake (-) Animal iron intake (-)			Vitamin C intake (+) Energy intake (%) from animal fat (-)
Serum vitamin B-12	Animal protein intake (+) Animal iron intake (+) Plant protein intake (-) Folate intake (-)	Laver intake (+) Energy intake (%) from total protein (+)		

+ positive correlation; - negative correlation.
p<0.05

ciation between serum vitamin B_{12} and the consumption of dairy product was found in all groups.

DISCUSSION

A diverse and balanced diet is considered best to provide all nutrients required for an adequate nutrient supply. All diets excluding a group of nutrients involve a risk of nutrient deficiencies. For vegetarians, iron and vitamin B-12 are nutrients likely to be insufficiently provided.

In order to achieve an optimal iron status, the amount of iron intake as well as iron bioavailability should be considered. A meatless diet has less of an effect on total iron intake; however, iron from this diet is generally less bioavailable than from an non-vegetarian diet.[22] In our study, the medians of total iron intake in Buddhist vegetarian nuns and non-vegetarian Catholic nuns were appropriate to Korean recommended daily intake (14 mg).[23] In contrast, even though non-vegetarian students had the highest intake of animal source iron, the total iron intake was much lower than the recommended daily intake. Iron bioavailability can be enhanced or inhibited by dietary factors, and the iron absorption rate varies more than tenfold depending on meal composition.[24] Vitamin C is known as the strongest enhancer of iron absorption and can improve the iron bioavailability in natural and fortified foods against inhibitors such as phytate, polyphenols, calcium, and protein in dairy products.[24-26] Thus, a high vitamin C intake by vegetarians can compensate for the low iron bioavailability in a vegetarian diet. In fact, vitamin C intake of our vegetarians was positively correlated with serum ferritin concentration. Additionally, even though the non-vegetarian students with the lowest vitamin C intake consumed the highest amount of animal source food, their serum ferritin concentration did not differ from that of Buddhist vegetarians and was even slightly lower than that of non-vegetarian Catholic nuns with a modest consumption of animal source food and a high intake of vitamin C simultaneously. Intake of animal source iron is associated with a high iron bioavailability; however, that alone does not seem to lead to an optimal iron status.[27]

Serum ferritin is the most sensitive indicator of depleted iron stores. The serum ferritin level of our vegetarians was comparable to that of other vegetarian women and higher than that of young vegan German women, whereas hemoglobin concentration was very similar.[28,29] It is a common finding that there is no significant difference in hemoglobin or serum ferritin concentrations between vegetarian and non- vegetarian women.[27,29-31]

As in other vegetarians,[28,31,32] grains, vegetables, legumes, and fruits were the main dietary sources of iron in the Buddhist vegetarians. Additionally, unlike Western vegetarians, they had an iron intake from sea vegetables (5%). Because sea vegetables contain no phytate, they are considered a good source of iron.[36] Besides, they contain vitamins, minerals, and trace elements, especially iodine which is also a nutrient of concern in vegetarian diets.[33-35] In contrast, breakfast cereals playing an important role as iron source in Western vegetarians,[28,32] were not consumed.

As ferritin is one of the acute-phase proteins that increases in the presence of infection or inflammation, the cut-off value for iron deficiency below 150 µg/mL may be not valid under inflammatory conditions.[36] Although we did not determine acute-phase proteins, our subjects were asked for their disease history instead. In the analysis, the subjects free of acute or chronic diseases and not taking any medication were included.

The median folate intake of all diet groups did not reach the amount of Korean recommended daily intake (400 µg).[23] Nevertheless, the serum folate levels of all 54 Buddhist vegetarians (range 14.30-45.3 nmol/mL), 31 non-vegetarian Catholic nuns (range 10.4-32.9 nmol/mL), and 29 non-vegetarian students except one (range 8.5-21.7 nmol/mL) fell within the normal level (>10 nmol/mL). The serum folate level of our vegetarians was lower than that of vegetarians in other studies.[29,37] As serum folate concentration is determined by recent dietary intake,[8] the lower levels may reflect that the blood samples were collected in winter and early spring when dietary folate sources were limited. Another explanation could be that our subjects did not consume folate fortified foods and therefore have lower folate intake compared to people eating fortified food. Furthermore, a serum folate level >45.3 nmol/mL may not be desirable, especially combined with low serum vitamin B-12, because it could mask vitamin B-12 deficiency (“folate trap”).[7]

The dietary sources of folate were mainly vegetables, grains, and legumes. As with dietary iron, sea vegetables were a good folate source for Buddhist vegetarians as well as the non-vegetarian, contributing 10-18% of total folate intake.

Main dietary sources of vitamin B-12 for vegetarians are milk and eggs, although dairy products contain very small amount of vitamin B-12 and bioavailability from eggs is low.[10,38] For Western vegetarians, especially vegans fortified foods increase vitamin B-12 supply.[39] As potential dietary sources of vitamin B-12 for Asian vegetarians, plant foods such as fermented soy products and seaweeds were investigated in many studies.[10-12,19,20] Most of them detected either exclusively vitamin B-12 analogues or traces of *true* vitamin B-12. Exceptionally, substantial amounts of vitamin B-12 were found in purple (*Porphyra sp.*) and green (*Enteromorpha sp.*) algae.[11,19-21,40] Vitamin B-12 content in laver varies depending on analysis method and species. Korean laver (*Porphyra tenera*) is the most commonly consumed seaweed species in Korea, as well as worldwide.[41] Kwak *et al*. found that 100 g of Korean laver products (*P. tenera*) contained 66.8 µg of vitamin B-12.[20] Miyamoto *et al*. reported a vitamin B-12 content in Korean dried laver (*P. tenera*) of 134 µg and in seasoned and toasted laver 51.7 µg.[19] Furthermore, no vitamin B-12 analogues were found in this laver. Similarly, raw laver (*P. tenera*) in the studies of Yamada *et al.* had a high proportion of *true* vitamin B-12 73-100%, whereas dried laver had only 35% *true* vitamin B-12.[11,21]

The bioavailability of vitamin B-12 in laver for human is still controversial. A Dutch study on macrobiotic children found laver (*P. tenera*), spirulina, and fermented plant foods not reliable as sources of vitamin B-12.[42] After consuming vitamin B-12 from only these plant foods for 5 months, MCV in five vegan children was even higher, despite increasing plasma vitamin B-12 levels. Methylmalonic acid is considered as the most important functional indicator for vitamin B-12, because this vitamin is necessary for the conversion of methylmalonyl CoA to succinyl CoA. In vitamin B-12 deficiency, methylmalonic acid concentration is high in serum and urine.[43] A study on the bioavailability of vitamin B-12 in laver using methylmalonic acid showed that raw laver was more reliable dietary source of vitamin B-12 for vegetarians than dried laver.[21] However in another study, six Japanese vegan children who daily consumed 2-4 g of dried laver had neither vitamin B-12 deficiency in blood nor neurological disturbances.[44]

In our study, most of the subjects consumed dried laver; however, only the vegetarian group showed a positive correlation between laver intake and serum vitamin B-12 levels. Buddhist vegetarians had a high serum vitamin B-12 concentration compared to other vegetarians.[29,37] On the basis of its high content of *true* vitamin B-12, Korean laver can be recommended for vegetarians as a dietary source of vitamin B-12.[10,19-21] Nevertheless, more studies on its bioavailability from Korean laver in vegetarians are desirable.

In contrast to other studies,[45-47] dairy intake had no effect on vitamin B-12 status here. One reason could be the low intake of dairy products. Korea is one of the countries with low milk consumption.[48] The National Health and Nutrition Survey reported that the average consumption of milk products of the female population was 70.6 g per day.[49]

In this study, the nutritional status of iron, folate, and vitamin B-12 in Buddhist vegetarians were appropriate. Although they had very low intake of animal source food, their prevalence of deficiencies of these nutrients did not differ from that of non-vegetarian who consumed larger amounts of animal source foods. High intake of vegetables and fruits was well reflected in the adequate serum folate status. In contrast to Western vegetarians, fortified foods and milk are not relevant dietary sources of iron, folate and vitamin B-12 for Korean vegetarians. Instead, sea vegetables contribute more to the supply of these nutrients. Therefore, dietary guidelines for Korean vegetarians based on Korean food culture should be developed.

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The Authors declare that they have no conflict of interest.

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Short Communication

The nutritional status of iron, folate, and vitamin B-12 of Buddhist vegetarians

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佛教素食者之鐵、葉酸及維生素 B-12 之營養狀況

本研究比較韓國素食者與非素食者之鐵、葉酸及維生素 B-12 之營養狀況。研究對象之素食者共 54 位比丘尼，其飲食除了乳製品以外，其它動物性來源食品皆不攝取。在非素食者部分分成兩組，分別為 31 位修女及 31 位女性大學生。研究方法：使用三天飲食記錄，同時收集血液樣本，分析完整血液指標與血清鐵蛋白、葉酸及維生素 B-12 濃度。結果發現不同飲食組別，其血紅素濃度沒有顯著差異。另外素食者血清鐵蛋白與血比容百分比，與有較高動物食品攝取量，及較低維生素 C 攝取量之非素食的大學生組相比，沒有顯著差異；但是與適量動物性食品攝取，及較高維生素 C 攝取之非素食修女組相比，則有較低的情況。除了一位素食者與一位非素食的大學生以外，所有研究對象的血清維生素 B-12 濃度與葉酸濃度，都在正常的範圍之內。在素食者發現，維生素 C 攝取量與血清鐵蛋白濃度存在正相關，另外紫菜攝取量與血清維生素 B-12 濃度也存在正相關。為了達到適當的鐵營養狀況，必須同時考慮鐵的攝取量及其生物利用率。適量血清葉酸濃度反映出受試者蔬果攝取充足。最後發現韓國的紫菜是素食者維生素 B-12 很好的來源。

關鍵字：鐵、葉酸、維生素 B-12、佛教素食者、 素食飲食

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