Summary
Inspite that rice is a main staple and heavily consumed in most of Asian populations, health effect of rice has been less examined in nutritional epidemiologic studies compared to those of foods such as fruits, vegetables, meats and fish. Some recent meta-analyses that collected prospective cohort studies reported the associations between rice intake and incidence of and mortality from some chronic diseases especially type 2 diabetes. Concerning type 2 diabetes, the results are remarkably different between white (polished) rice and brown (unpolished) rice: the former increased and the latter decreased the risk. This difference may partly be explained by the different types and amounts of dietary fiber and different scores of dietary glycemic index. However, the results on dietary fiber and dietary glycemic index were not necessarily consistent. Indirect effect of rice intake has been examined through the studies on association of dietary patterns and breakfast skipping to type 2 diabetes. However, most of the results were inconclusive. Simple and straightforward judgement on the effect of rice to type 2 diabetes should be avoided, and more nutritional epidemiologic studies with high research quality, including basic studies on dietary assessment, are needed, especially in Asian populations.

Key Words
rice, epidemiology, type 2 diabetes, prevention, diet
and women living in Singapore, no significant risk difference was observed between the groups by rice intake (4). However, this study reported that replacing one daily serving of rice with noodles, red meat, or poultry was associated with increased risk of type 2 diabetes, whereas the replacement of rice with white bread or wholemeal bread was associated with decreased risk of type 2 diabetes. This subanalysis indicates a possibility of indirect, rather than direct, effect of rice to type 2 diabetes through other foods influenced by rice intake.

**Carbohydrate and type 2 diabetes**

A meta-analysis with 21 cohort studies showed no clear association between habitual carbohydrate intake and incidence of type 2 diabetes: the summary relative risk was 0.97 per 50 g/day increase in carbohydrate (95% CI 0.90–1.06; p = 0.5) (5). Non-linear dose-response meta-analysis even found decreasing risk in the upper half of rice intake. It means that carbohydrate intake does not have a direct association with incidence of type 2 diabetes. A large-scale cohort study conducted in eight European countries reported no significant association between carbohydrate intake and incidence of type 2 diabetes (6).

In one Japanese cohort study, a significant risk increase was observed in the group with the highest intake of carbohydrate in women, but not in men, after adjusting for potential confoundings (7). In another Japanese cohort study, a significantly positive association was observed only in obese and overweight men, but not in non-obese men (8). In Chinese women, a weak but significant risk increase was observed in the group with the highest intake of carbohydrate (3). Thus, the results are inconclusive also in Asian populations.

**Glycemic index and type 2 diabetes**

In contrast of carbohydrate, dietary glycemic index showed almost linear and significantly positive association with incidence of type 2 diabetes in the same meta-analysis above: the summary relative risk was 1.08 per 5 glycemic index units (95% CI 1.02–1.15; p = 0.01) (5). A large-scale cohort study conducted in eight European countries reported no significant association between dietary glycemic index and incidence of type 2 diabetes (6). Not a few studies showed even significantly negative association of dietary glycemic index with incidence of type 2 diabetes. One Japanese cohort study reported a significantly positive association of high dietary glycemic index and incidence of type 2 diabetes in non-obese men (9). In contrast, another Japanese cohort study reported no significant association (10). Therefore, the results are not yet conclusive, and further studies with high research quality are needed.

Average glycemic index is considerably higher in Japanese adults of 65.9 (SD = 4.9) in men and 63.9 (SD = 5.0) in women (11), compared to the average values in Western populations such as 56.9 and 55.5 in US men and women, respectively (12), 59.5 and 58.3 in British men and women, respectively (13), and 56.9 and 55.5 in Australian men and women, respectively (14). This may be one of the reasons why the prevalence of type 2 diabetes is relatively high in Asian populations compared to those in Western populations regardless of the relatively low prevalence of overweight and obesity in Asian populations (15, 16). Further studies on this issue are urgently needed.

**Dietary fiber and type 2 diabetes**

Dietary fiber is one of the important contributors to low dietary glycemic index. Several nutritional epidemiologic studies reported a negative (favorable) association between dietary fiber intake and incidence of and mortality from major chronic diseases such as coronary heart disease and cardiovascular disease (17).

However, association between dietary fiber intake and incidence of type 2 diabetes was complicated and different from those observed in coronary heart disease and cardiovascular disease. In a meta-analysis that examined cohort studies, a significant and negative association with incidence of type 2 diabetes was observed only for cereal fiber, but neither for fruit fiber nor vegetable fiber (18). This is confirmed by a recent meta-analysis with dose-response analysis (19). These results suggest some specific effects of dietary fiber contained in cereals against type 2 diabetes.

**Whole grain and type 2 diabetes**

Several nutritional epidemiologic studies reported a reduction of incidence of type 2 diabetes by whole grain intake (20). A meta-regression analysis showed almost linear decrease by increase in whole grain intake (20). But whole grain in the studies included in this meta-analysis was not rice, but rye, barley, and wheat. Therefore, the brown rice (unrefined rice) cannot be recommended directly by this result.

Three US studies compared the risks to type 2 diabetes, by pooling the data, between white (polished) rice and brown (unpolished) rice (21). Higher intake of white rice was associated with an increased risk of type 2 diabetes: the pooled relative risk was 1.17 (95% CI, 1.02–1.36). In contrast, high brown rice intake was associated with a decreased risk of type 2 diabetes: the pooled relative risk was 0.89 (95% CI, 0.81–0.97). This result supports a favorable effect of brown rice to prevent type 2 diabetes.

**Rice-based dietary pattern and type 2 diabetes**

Meta-analysis reported, in general, a positive association of healthy/prudent dietary pattern and a negative association of unhealthy/Western dietary pattern with incidence of type 2 diabetes (22, 23). In many studies, healthy/prudent dietary pattern and unhealthy/Western dietary pattern included, as a major food component, high level of or frequent intake of whole (unpolished) grain, and those of polished grains, respectively.

However, one Japanese cohort study that examined association between dietary pattern and incidence of type 2 diabetes found no significant association with any of three dietary patterns identified: either prudent, westernized, or traditional Japanese patterns (10). However, the factor loading on rice was relatively small even in traditional Japanese patterns. Therefore, type 2 diabetes risk of rice-based dietary pattern is unknown. One Chinese cohort study reported a negative association of grains-vegetables dietary pattern score with incidence
of type 2 diabetes (24). Whole grain, but not refined grains, was one of the major components of this dietary pattern.

The dietary pattern with refined and unrefined grains as major food component may be associated with increased and decreased incidence of type 2 diabetes, respectively. But further studies are needed for dietary pattern characterized by rice.

**Breakfast skipping and type 2 diabetes**

Japanese, for example, consumes approximately 28% of energy only from rice (25). Therefore, energy balance between breakfast, lunch, and dinner mainly depends on rice consumption in each meal. Because of second-meal effect, blood glucose after lunch increases more when breakfast is skipped than when breakfast was taken even if energy consumption at lunch is the same (26). Therefore, habitual breakfast skipping is hypothesized as a risk of type 2 diabetes. A meta-analysis examined association of breakfast skipping and incidence of type 2 diabetes, with 6 cohort studies, reported a significantly positive association. In a dose-response analysis, the risk increased up to 4 d of breakfast skipping, and no further increase was observed after 5 d of breakfast skipping (27). But this meta-analysis, also the cohort studies included in this meta-analysis, did not consider the foods consumed at breakfast. Therefore, contribution and meaning of rice at breakfast to type 2 diabetes risk is unknown.

**Methodological limitations**

Validity of measurement for exposure variables, rice intake on this issue, is a key to assure the quality of epidemiologic studies. Validity of dietary assessment methods usually used in nutritional epidemiologic studies such as food frequency questionnaires are not promising so as to the expectation. Because the risk reported in the studies included in this article heavily depends on the validity of the dietary assessment methods, simple comparison of the risks is not recommended. In addition, we cannot know energy intake with the dietary assessment questionnaires mostly used in nutritional epidemiologic studies because of the very low validity (28). This is one of the serious limitations on this issue.

**Conclusion**

Some recent meta-analyses that collected prospective cohort studies reported the associations between rice intake and incidence of type 2 diabetes. The results are remarkably different between white (polished) rice and brown (unpolished) rice: the former increased and the latter decreased the risk. This difference may partly be explained by the different types and amounts of dietary fiber and different scores of dietary glycemic index. However, the results on dietary fiber and dietary glycemic index were not necessarily consistent. Indirect effect of rice intake has been examined through the studies on association of dietary patterns and breakfast skipping to type 2 diabetes. However, most of the results were inconclusive. Simple and straightforward judgement on the effect of rice to type 2 diabetes should carefully be avoided, and more nutritional epidemiologic studies with high research quality, including basic studies on dietary assessment, are needed, especially in Asian populations.

**Disclosure of State of COI**

Sasaki S has no conflict of interest.

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