JDI Journal of Diabetes Investigation Open access
Official Journal of the Asian Association for the Study of Diabetes
JDI UPDATES

Dietary recommendations for type 2 diabetes patients: Lessons from recent clinical and basic research in Asia

Medical nutrition therapy (MNT) can play a significant role in the treatment of type 2 diabetes. In clinical settings, when glycemic control or bodyweight worsens, patients and healthcare professionals should consider the cause and an appropriate strategy for remediation. Furthermore, the beneficial effects of the now widely used glucose-lowering agents, dipeptidyl peptidase-4 (DPP-4) inhibitors and sodium–glucose cotransporter 2 inhibitors, are considerably influenced by body mass index (BMI) and dietary habits.

Inappropriate eating behaviors, together with inadequate exercise, psychological stress and insufficient sleep duration all contribute to poor glycemic control and bodyweight gain. Bad eating habits can be due to overwork, waking up late, consuming greater amounts of food as a late evening meal, and skipping breakfast because of lack of appetite and/or time. Skipping breakfast and eating late evening meals has been shown to be associated with poor glycemic control in young male Japanese type 2 diabetes patients[1]. In addition, obese type 2 diabetes patients (BMI $\geq$30 kg/m^2) show higher hedonic hunger analyzed by the power of food scale compared with non-obese type 2 diabetes patients; there is a positive linear association between hedonic hunger and poor glycemic control in obese type 2 diabetes patients, but not in non-obese type 2 diabetes patients[2]. Furthermore, self-reported energy intake does not differ between healthy individuals and type 2 diabetes patients (BMI <30 kg/m^2) with relatively good glycemic control (average glucose levels 117 $\pm$ 16 and glycated hemoglobin 6.4 $\pm$ 0.5%)[3]. These results show that eating breakfast and reducing the energy content of evening meals is important for restraining bodyweight gain and hedonic hunger, and maintenance of good glycemic control in type 2 diabetes patients.

Mice fed a high-starch diet, the final product of which is glucose, show obesity[4]; mice fed a high-sucrose diet, the final product of which is glucose and fructose, show glucose intolerance due to reduced glucokinase activity in the liver and impaired glucagon-like peptide-1 secretion[5], showing that a high-carbohydrate diet contributes to bodyweight gain and worsens glycemic control. Indeed, glycated hemoglobin levels were found to be positively correlated with carbohydrate intake and BMI in Japanese type 2 diabetes patients[6]. In addition, glycated hemoglobin levels have been shown to be negatively correlated with fiber intake in Japanese type 2 diabetes patients[6].

Medical nutrition therapy involving low-carbohydrate diets, low glycemic index diets and fiber-rich diets can ameliorate postprandial glucose excursion in type 2 diabetes patients. A low-carbohydrate diet derived from changing only the staple food consisting mainly of carbohydrate from normal-carbohydrate bread to low-carbohydrate bread, which changes the carbohydrate content from 48.8 to 35.5% of total calories in the meal, was shown to decrease postprandial plasma glucose levels in type 2 diabetes patients despite their taking diabetic medications[7]. Reducing carbohydrate content in diets from 55% energy to 40% energy or replacing high glycemic index food with low glycemic index food (e.g., replacing white rice with brown rice) has also been shown to ameliorate postprandial glucose elevation[8]. Interestingly, γ-oryzanol contained in brown rice not only improves glucose-induced insulin secretion, but also provides an anti-obesity effect by decreasing the desire for an animal fat-rich diet[9]. It is widely accepted that dietary fiber intake ameliorates postprandial glucose elevation by reducing glucose absorption from the intestine. The recent study also showed that vegetable intake is higher among type 2 diabetes patients with good glycemic control compared with that among type 2 diabetes patients not having good glycemic control. The same study revealed that vegetable intake among type 2 diabetes patients is inversely associated with nocturia, which might disturb a patient's quality of sleep and thereby contribute to hypertension and hyperglycemia[10].

Preloading of a protein-rich diet and fiber-rich diet before carbohydrate intake has been gaining attention as a novel MNT that can prevent postprandial glucose elevation in type 2 diabetes patients, as well as in healthy individuals[11–13]. Preloading of a protein-rich diet before carbohydrate intake attenuates postprandial glucose excursion, especially in type 2 diabetes patients[11,12]. Slowing gastric emptying and enhancing early-phase insulin secretion by increasing secretions of glucagon-like peptide-1, glucagon and glucose-dependent insulinotropic polypeptide (GIP) might contribute to the decreased postprandial glucose levels[11,12]. Vegetables abundant in fiber are thought to delay glucose absorption, and preloading of vegetables before

*Corresponding author. Yusuke Seino
Tel.: +81-562-93-9242
Fax: +81-562-95-1879
E-mail address: seinoy@fujita-hu.ac.jp
Received 23 August 2019; revised 27 August 2019; accepted 28 August 2019

carbohydrate intake decreases postprandial glucose levels both in non-diabetic individuals and type 2 diabetes patients without enhancing early-phase insulin secretion[13] or delaying gastric emptying (Yabe, data not shown). Thus, combining preloading of a protein-rich diet with fiber-rich diet might maximize their effects on postprandial glucose elevation.

The effects of MNT on the efficacy and safety of glucose-lowering agents, such as DPP-4 inhibitors and sodium–glucose cotransporter 2 inhibitors, are an intriguing area of investigation[8,14]. Recently, it has been reported that in some type 2 diabetes patients who consume more fats, but not more carbohydrates, DPP-4 inhibitor treatment increases bodyweight, probably through enhancement of GIP secretion and action, and its glucose-lowering effects are impaired for several months after initiation of DPP-4 inhibitor treatment[14]. In animal experiments, both wild-type mice fed a high-fat diet and high-starch diet show obesity and enhanced glucose-induced insulin secretion. Importantly, bodyweight gain and enhanced glucose-induced insulin secretion are not observed in GIP receptor-deficient mice fed a high-fat diet, but occur in GIP receptor-deficient mice fed a high-starch diet[15]. These results suggest that GIP contributes to fat-rich diet-induced bodyweight gain, but not to carbohydrate-rich diet-induced bodyweight gain.

Considering these recent findings on MNT, which dietary plans can be recommended clinically to better maintain good glycemic control and bodyweight in type 2 diabetes patients? First, type 2 diabetes patients should start the day with breakfast and not consume food in the late evening. Second, they should use brown rice rather than white rice and a low-carbohydrate bread rather than normal bread with vegetables. Alternatively, they should be urged to eat vegetables with abundant fiber and meat or fish containing a large amount of protein first, and then, after a short interval, to eat the carbohydrates of the meal, including the staple food. This meal sequence mimics that of the traditional Japanese "Kaiseki" cuisine, the individual dishes of which are shown together in Figure 1.

DISCLOSURE

YS received a scholarship grant from Grants-in-Aid for Scientific Research from Japan Society for the Promotion of Science (17k09823), Suzuken Memorial Foundation, Novo Nordisk Pharma Ltd., MSD K.K., Pfizer., Mitsubishi Tanabe Pharma., Eli Lilly and Company., Novartis Pharma., and Daiichi Sankyo Company Ltd. DY received consulting or speaker fees from MSD K.K., Novo Nordisk Pharma Ltd. and Taisho Toyama Pharmaceutical Co. Ltd. D Yabe also received clinically commissioned/joint research grants from Taisho Toyama Pharmaceutical Co. Ltd., Ono Pharmaceutical Co. Ltd., Novo Nordisk Pharma Ltd., Arklay Co. Ltd. and Terumo Co. Ltd. AS received consulting or speaker fees from Asahi Kasei Pharma Co., Astellas Pharma Inc., Daiichi Sankyo Co, Ltd., Eli Lilly and Company., Mitsubishi Tanabe Pharma., MSD K.K., Pfizer, and Taisho Toyama Pharmaceutical Co. Ltd. AS received research support from Chugai Pharmaceutical Co. Ltd., MSD K.K., Ono Pharmaceuticals Co. Ltd. and Takeda Pharmaceutical Co. Ltd.

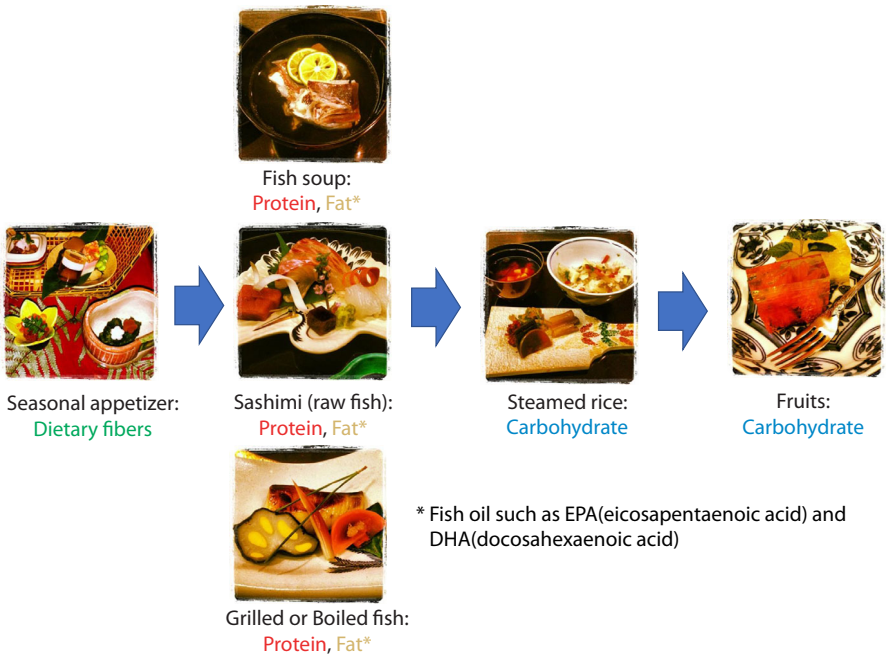

Figure 1 | In practice, "Kaiseki" is carefully sequenced in its service. Dishes containing dietary fibers are eaten first, and the protein and fat courses are then followed by the carbohydrate dishes. Such a sequenced meal markedly improves postprandial glucose excursion, gastric emptying and incretin secretion in individuals with and without diabetes.

Yusuke Seino[1,*], Shinji Ueno[1], Daisuke Yabe[2,3,4], Atsushi Suzuki[1]
[1]*Department of Endocrinology and Metabolism, Fujita Health University, Toyoake,* [2]*Department of Diabetes and Endocrinology, Gifu University Graduate School of Medicine, Gifu,* [3]*Yutaka Seino Distinguished Center for Diabetes Research, Kansai Electric Power Medical Research Institute, and* [4]*Division of Molecular and Metabolic Medicine, Kobe University Graduate School of Medicine, Kobe, Japan*

REFERENCES

1. Azami Y, Funakoshi M, Matsumoto H, *et al*. Long working hours and skipping breakfast concomitant with late evening meals are associated with suboptimal glycemic control among young male Japanese patients with type 2 diabetes. *J Diabetes Investig* 2019; 10: 73–83.
2. Cheung LTF, Ko GTC, Chow FCC, *et al*. Association between hedonic hunger and glycemic control in non-obese and obese patients with type 2 diabetes. *J Diabetes Investig* 2018; 9: 1135–1143.
3. Yoshimura E, Ohkawara K, Ishikawa-Takata K, *et al*. Assessment of energy expenditure using doubly labeled water, physical activity by accelerometer and reported dietary intake in Japanese men with type 2 diabetes: A preliminary study. *J Diabetes Investig* 2019; 10: 318–321.
4. Murase M, Seino Y, Maekawa R, *et al*. Functional adenosine triphosphate-sensitive potassium channel is required in high-carbohydrate diet-induced increase in β-cell mass. *J Diabetes Investig* 2019; 10: 238–250.
5. Sakamoto E, Seino Y, Fukami A, *et al*. Ingestion of a moderate high-sucrose diet results in glucose intolerance with reduced liver glucokinase activity and impaired glucagon-like peptide-1 secretion. *J Diabetes Investig* 2012; 3: 432–440.
6. Yamakawa T, Sakamoto R, Takahashi K, *et al*. Dietary survey in Japanese patients with type 2 diabetes and the influence of dietary carbohydrate on glycated hemoglobin: The Sleep and Food Registry in Kanagawa study. *J Diabetes Investig* 2019; 10: 309–317.
7. Ando MK, Seino Y, Morikawa R, *et al*. Low-carbohydrate diet by staple change attenuates postprandial GIP and CPR levels in type 2 diabetes patients. *J Diabetes Complications* 2019. https://doi.org/10.1016/j.jdiacomp.2019.107415
8. Yabe D, Iwasaki M, Kuwata H, *et al*. Sodium-glucose co-transporter-2 inhibitor use and dietary carbohydrate intake in Japanese individuals with type 2 diabetes: A randomized, open-label, 3-arm parallel comparative, exploratory study. *Diabetes Obes Metab* 2017; 19: 739–743.
9. Masuzaki H, Kozuka C, Okamoto S, *et al*. Brown rice-specific γ-oryzanol as a promising prophylactic avenue to protect against diabetes mellitus and obesity in humans. *J Diabetes Investig* 2019; 10: 18–25.
10. Furukawa S, Sakai T, Niiya T, *et al*. Dietary intake habits and the prevalence of nocturia in Japanese patients with type 2 diabetes mellitus. *J Diabetes Investig* 2018; 9: 279–285.
11. Kuwata H, Iwasaki M, Shimizu S, *et al*. Meal sequence and glucose excursion, gastric emptying and incretin secretion in type 2 diabetes: a randomised, controlled crossover, exploratory trial. *Diabetologia* 2016; 59: 453–461.
12. Bae JH, Kim LK, Min SH, *et al*. Postprandial glucose-lowering effect of premeal consumption of protein-enriched, dietary fiber-fortified bar in individuals with type 2 diabetes mellitus or normal glucose tolerance. *J Diabetes Investig* 2018; 9: 1110–1118.
13. Imai S, Fukui M, Kajiyama S. Effect of eating vegetables before carbohydrates on glucose excursions in patients with type 2 diabetes. *J Clin Biochem Nutr* 2014; 54: 7–11. Review
14. Kuwata H, Okamoto S, Seino Y, *et al*. Relationship between deterioration of glycated hemoglobin-lowering effects in dipeptidyl peptidase-4 inhibitor monotherapy and dietary habits: Retrospective analysis of Japanese individuals with type 2 diabetes. *J Diabetes Investig* 2018; 9: 1153–1158.
15. Maekawa R, Ogata H, Murase M, *et al*. Glucose-dependent insulinotropic polypeptide is required for moderate high-fat diet- but not high-carbohydrate diet-induced weight gain. *Am J Physiol Endocrinol Metab* 2018; 314: E572–E583.

Doi: 10.1111/jdi.13135