Energy Providing Nutrients' Balance

1. Background Information

Energy providing nutrients' balance is the ratio of energy providing nutrients (macronutrients-- namely protein, fat and carbohydrate) including alcohol and the individual components for a particular food item. The current DRIs are determined based on the energy intakes from these nutrients and expressed as the percentage of energy intake (%E). Achieving a balance in the intakes of aforementioned nutrients is aimed at the prevention of not only their inadequate intake, but also the development of lifestyle-related diseases (LRDs). In the prevention of LRD development, nutrient balance should be achieved, based on meeting requirements to avoid inadequacy. Thus, the DRIs for energy-providing nutrients' balance should focus on the tentative dietary goal for preventing LRDs (DGs).

In terms of energy-providing nutrients, protein intake must meet the estimated average requirement (EAR). To avoid insufficiency, it is recommended that the intake be above the recommended dietary allowance (RDA). In terms of fat, adequate intake (AI) is set for n-6 and n-3 fatty acids, while DGs are set for saturated fatty acids. Although carbohydrate is an essential nutrient, its intake is likely to exceed the requirement except under specific conditions.

Therefore, it is appropriate to first determine the amount of protein, followed by that of fat, with the carbohydrate amount set as the residual value for the energy-providing nutrients' balance. While alcohol provides energy, it is not an essential nutrient, and there is no reason to recommend its intake. If alcohol is included in the nutrients' balance, the rest of the protein and fat components are derived from the amount of carbohydrate and alcohol.

For infants aged under 1 year, a desirable nutrients' balance is achieved through the consumption of breast milk. Therefore, the energy-providing nutrients' balance was determined for those aged over 1 year in the DRIs.

2. Energy Conversion Factor

There are slight differences in the energy conversion factors for protein, fat, carbohydrate, and alcohol, depending on the foods from which these nutrients are obtained(1). The Atwater factor is used for the approximation of values (protein, carbohydrate: 4, fat: 9), without consideration of the above-stated differences. It also does not consider the different types of components that comprise these nutrients, namely amino acids, fatty acids, and sugars.

The amount of energy produced by dietary fiber is considered to be 0-2 kcal/g(2), which is lower than that produced by other carbohydrates. Among carbohydrates, dietary fiber should not be included as a source of energy. However, from the standpoint of the applicability and feasibility of the DRIs, the energy-providing nutrients' balance includes dietary fiber as carbohydrates, and 4 kcal/g is used as its energy conversion factor.

In Japan, 7.1 kcal/day is the amount of energy obtained from alcohol(1). However, here, we used the value "7 kcal/g", as the energy conversion factors of the other nutrients are integers.

3. For the Prevention of LRD Development and Progression

It is important for the protein intake to be above the RDA, or at least on par with the EAR. We reviewed studies focusing on protein intakes above the EAR or RDA, from the standpoint of the prevention of LRD development and progression.

In terms of dietary fat, a high intake of saturated fat is a major issue, in this context. Several studies have examined the association between low fat intake and health status.

3─1. Prevention of LRD Development

3─1─1. Protein

According to a US cohort study examining the association between protein intake and estimated glomerular filtration rate (eGFR) in women, a significant decrease in the eGFR was observed among high-protein intake (median: 92 g/day) participants with a slightly low renal function level, while there was no significant association among those with normal renal function levels(3).

In another US cohort study examining the association between low-carbohydrate diet and the development of diabetes, the incidence of diabetes was significantly higher in men with a low-carbohydrate and high-animal-protein diet than in those in other groups, with no such results being observed for low-carbohydrate and high-plant-protein diets(4). This finding suggests the importance of considering the influence of the quality of the proteins (amino acids) consumed or their dietary sources on the intakes of other nutrients, rather than the total protein intake. Additionally, the same cohort study reported that the all-cause mortality was significantly higher among men with a low-carbohydrate and high-animal-protein diet, and significantly lower in men with a low-carbohydrate and high-plant-protein diet(5). Similar results were observed in a cohort of American women(5). Although the aforementioned studies did not directly examine the influence of the differences in the amounts of total protein intake, their results suggest that dietary protein sources and the amount consumed may affect health status. A cohort study has shown a significantly higher incidence of cardiovascular diseases in those consumed low-carbohydrate diets (= high-protein diets) in Swedish women(6). It is needed to interpret these results considering the quality of protein (amino acids) and its dietary sources.

A significant negative association was reported between protein intake and the incidence of frailty among elderly American people (aged 65-79 years)(7). In that study, participants were classified into quintiles, according to their protein intake, with those with an intake of 12.4%E in the lowest quintile and those with an intake of 16.0%E in the highest quintile. A Japanese cross-sectional study reported that the prevalence of frailty was significantly lower in those with a protein intake greater than 16.1%E, among 2,108 elderly women (aged 65 years or older)(8).

3─1─2. Dietary Fat

Several studies have focused on the association between fat intake and changes in body weight (BW) later in life. However, the results are inconsistent, with most studies reporting no significant association. A US-based study reported a significant association between fat intake and BW gain only among women younger than 50 years(9), while a European study reported no significant association in any sex or age group(10).

The development of LRDs is affected largely by fatty acid intake (especially saturated fatty acids), rather than total fat intake. This association has been established for myocardial infarction(11), as well as diabetes(12). Thus, it is important to consider the quality of the fats (especially saturated fatty acids) consumed, for the prevention of LRDs.

3─1─3. Carbohydrate

A meta-analysis showed an increased all-cause mortality in those with low-carbohydrate diets, while no association with cardiovascular mortality and incidence was observed(13). However, it is difficult to use these data for the DRIs because this meta-analysis did not report the carbohydrate intake amount.

The development of LRDs is largely influenced by the intake of dietary fiber, the glycemic index of the food consumed, and the types of sugar (monosaccharide, disaccharide or polysaccharide), rather than the total carbohydrate intake amount. For example, some studies have reported on the protective effect of grain dietary fiber(14), dietary glycemic index, and glycemic load(15,16) against diabetes development, and the association between the massive intake of sugar-sweetened beverages and obesity(17,18). Therefore, the quality of the carbohydrate consumed is of significance. However, a study reported that there was no significant association between carbohydrate intake and dietary glycemic index, and the development of diabetes(19). At present, these results are inconsistent and further investigation is needed.

3─2. Prevention of LRD Progression

3─2─1. Protein

A meta-analysis summarized the interventional trials that examined the influence of high-protein diets on cardiovascular diseases and metabolic risk factors compared to that of low-protein diets, over a period of more than 12 months(20). The meta-analysis found no significant difference in the BW, waist circumference, serum low-density lipoprotein (LDL) cholesterol level, triglyceride level, blood pressure, fasting blood glucose level, and glycated hemoglobin (HbA1c) level between those with a high-protein diet (30%E in most trials) and those with a low-protein diet (15%E in most trials). In an interventional trial that examined middle-aged obese participants for 2 years, there was no significant difference in the BW change between those with high-protein diets (25%E) and those with low-protein diets (15%E)(21).

Another interventional study of obese patients with diabetes reported a significant BW loss with no significant change in fasting blood glucose and HbA1c levels for 12 months for high protein diet(22), while another study reported there was no significant change in any of the outcomes(21).

A meta-analysis including relatively short-term interventional studies (mean: 12 weeks) reported that significant improvements were observed in BW, body fat, and triglyceride levels in those with high-protein diets (30%E)(23). While several short-term intervention studies have reported positive results for the progression of LRDs through the intake of high-protein diets, few studies included long-term interventions.

3─2─2. Dietary Fat

A meta-analysis summarized interventional studies which examined the effect of low-fat diets (20-30%E in most studies) on blood lipids levels, for more than 12 months(24). The results showed a significant decrease not only in serum LDL cholesterol levels, but also a significant decrease in serum high-density lipoprotein (HDL) cholesterol levels, and a significant increase in triglyceride levels. Another meta-analysis summarizing 6-month interventions showed a similar result, with no significant difference observed in the blood pressure, fasting blood glucose level, and fasting insulin level(25). Another meta-analysis of 19 interventional studies including diabetes patients reported that low fasting insulin and triglyceride levels and high HDL cholesterol levels were observed in those with high-fat diets (low-carbohydrate) compared to those with low-fat diets (high-carbohydrate); no significant differences were noted in the HbA1c, fasting blood glucose, total cholesterol, and LDL cholesterol levels(26).

In an interventional study of middle-aged obese participants, no significant difference was noted in the BW change between individuals with low-fat diets (20%E) and those with high-fat diets (40%E), over a 2-year period(21). However, in another interventional study of middle-aged participants, a greater BW loss was observed in those with high-fat diets (38%E) than those with low-fat diets (30%E), over a 2-year period(27); in that study, the composition of the fatty acids were different between the two diets. A meta-analysis reported a greater BW loss in those with low-fat diets by summarizing 33 interventional studies that examined the effect of decreased dietary fat intake on BW changes(28). In that meta-analysis, the dietary fat intake before the interventions was reported as 28-43%E; therefore, the results cannot be interpreted beyond this range.

Yet another meta-analysis stratified interventional studies examining the effects of low-fat diets on BW and blood lipids, by interventional period; 6 months vs. 12 months(29). In that study, a significant BW loss was observed in the 6-month long trial, but not in the 12-month long trial; no significant effect was observed for blood lipids.

Overall, the influence of total fat intake on health is not as obvious as previously expected, and study results are inconsistent. However, it seems preferable to maintain a lower fat intake, within the range of 28-43%E, from the standpoint of BW management. However, total fat also includes essential fatty acids. Since the requirements for these fatty acids vary by groups or individuals, the DG for total fat should be set so as to meet the AI of essential fatty acids, considering differences between the life stages. Additionally, several studies have reported that saturated fatty acids have unfavorable effects on several LRDs. Therefore, the DG of total fat should be set such that it does not exceed the DG of saturated fatty acids. Therefore, the DG of total fat should be set within the range observed in the study results, at a value that reduces the health effects of saturated fatty acids as much as possible. Thus, saturated fatty acids must be included in the energy-providing nutrients' balance, considering their health effects.

3─2─3. Carbohydrate

Some meta-analyses have suggested that low-carbohydrate diets may be effective for BW loss and diabetes control(30,31). However, most of those meta-analyses did not provide details on the diets, such as the diet compositions of the control groups.

Another meta-analysis reported that dietary fiber supplementation led to significant decreases in fasting blood glucose and HbA1c levels among patients with diabetes(32). It is possible that carbohydrate quality is also important for the prevention of the development and progression of LRDs. However, further investigation is required.

4. Method Used to Set the DG

4─1. Basic Concept

The achievement of energy-providing nutrients' balance is directly and strongly associated with the prevention of LRD development or progression. However, the type of fatty acid (especially saturated fatty acids), dietary fiber as a carbohydrate, or the source of protein may play a rather more important role. Considering that total fat includes saturated fatty acids and carbohydrate includes dietary fiber, the DG of the energy-providing nutrients' balance was determined in the current DRIs using the methods stated in the following paragraphs. These DG ranges are approximate, however, and the balance needs to be considered in relation with other dietary energy and nutrient intakes.

4─2. Protein (DG)

The lowest DG value was set above the RDA of protein. On expressing the protein/energy ratio of the RDA value (g/day) using estimated energy requirements (EERs: kcal/day) for physical activity level (PAL) I (low), in each age and sex group, the ratio can be calculated as a maximum of 13.3%E in women aged 70 years or older. If pregnant women (in the late stages of pregnancy; aged 18-29 years) and lactating women are included, the maximum ratio can be calculated as 14.3%E. The protein intake should meet the requirement even if the energy intake is low. Considering the importance of protein intake, it may be safe to set values that are higher than the calculated RDA for the DG.

The highest DG value should be set considering the upper limit (UL). Although there is no UL for protein, some studies recommended an intake level of less than 2.0 g/kg BW/day for adults, especially among elderly individuals, from the standpoint of the prevention of unfavorable metabolic changes as well as azotemia(33,34). Using this value and the EER for PAL II (middle), the protein/energy ratio can be calculated as 19-22%E (in those aged 18-69 years) and 22-23%E (in those aged 70 years and older).

Based on the above-stated estimation, the DG of the protein/energy ratio was determined as 13-20%E. Elderly people (for the prevention of frailty), and pregnant and lactating women (for children's growth) should ensure their protein intake does not reach the lowest range.

4─3. Fat (DG)

The lowest DG value of the fat/energy ratio was set to secure the AI of essential fatty acids. Therefore, while this value is not aimed at the prevention of LRDs, ensuring the intake meets the AI is of high priority in the prevention of deficiency. For this reason, the lowest DG value for fat was determined considering the AI of essential fatty acids (n-6 and n-3 fatty acids). For more details, see "Dietary Fat."

The highest fat/energy ratio of the DG was determined considering the DG of saturated fatty acids. Most studies examining the health effect of total fat intake used a fat intake value of 30%E for low-fat diets; it is difficult to examine the health effect of fat intakes lower than this value. A meta-analysis (including 33 interventional studies) reported that a greater BW loss was observed in those whose fat intake decreased from 28-43%E(28), suggesting that the results cannot be interpreted beyond this range. Overall, evidence suggesting that a fat/energy ratio lower than 30%E be adopted as the highest DG value of fat is insufficient. Thus, the DG of the fat/energy ratio was determined as 20-30%E.

For saturated fatty acids, the DG was determined as 7%E or less. The DG of saturated fatty acids was not set for children aged 1-17 years due to a lack of data. However, this does not invalidate the need of considering excessive intake of saturated fatty acids in children.

It is necessary to pay attention to the quality of fat consumed, including that of essential fatty acids, as well as the amount of total fat and saturated fatty acids consumed.

4─4. Carbohydrate (DG)

The carbohydrate/energy ratio, including alcohol, was set as the value of the residual energy ratio of protein and total fat. A high-carbohydrate diet, without quality consideration, may be unfavorable, comprising only highly-refined cereals, sweeteners, sweetened beverages, and alcoholic beverages. Such diets can also lead to an insufficient intake of many vitamins and minerals, as these foods contain lower amounts of vitamins and minerals than other foods. If the lowest energy ratios of protein (13%E) and total fat (20%E) are used, the carbohydrate energy ratio can be calculated as 67%E. Therefore, the highest value of the carbohydrate DG was set at 65%E. It should be noted that the sum of the lowest values of the energy ratio of protein, fat and carbohydrate is not 100%.

The lowest carbohydrate DG value was set according to the highest values of the energy ratios of protein (20%E) and total fat (30%E). It is important to pay attention to carbohydrate quality to ensure the dietary fiber intake does not decrease, in the case of low-carbohydrate diets.

DRIs for Energy Providing Nutrient Balance (% energy)

<table>
<tr><th colspan="5">DG [1] (median [2]) (For both males and females)</th></tr>
<tr><th rowspan="3">Age etc.</th><th rowspan="3">Proteins</th><th colspan="2">Fats [3]</th><th rowspan="3">Carbohydrates [4,5]</th></tr>
<tr><th rowspan="2">Fats</th><th></th></tr>
<tr><th>Saturated fatty acid</th></tr>
<tr><td>0-11 months</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>1-17 years</td><td>13-20（16.5）</td><td>20-30（25）</td><td>—</td><td>50-65（57.5）</td></tr>
<tr><td>18-69 years</td><td>13-20（16.5）</td><td>20-30（25）</td><td>≤ 7</td><td>50-65（57.5）</td></tr>
<tr><td>70+ years</td><td>13-20（16.5）</td><td>20-30（25）</td><td>≤ 7</td><td>50-65（57.5）</td></tr>
</table>

[1] Ranges for each nutrient are expressed as approximate values. The present table shall be applied flexibly if used for the purpose of prevention of LRDs or frailty of elderly persons.

[2] Medians indicate the median values for the given range. They do not indicate most desirable values.

[3] Fats require careful consideration on their qualities, such as their component fatty acids (e.g., saturated fatty acids).

[4] Includes alcohol. However, it does not imply recommendation of alcohol consumption.

[5] Pay extra attention on DGs for dietary fibers.

References

1. The Council for Science and Technology, Ministry of Education, Culture, Sports and Technology (2010) *Standard tables of food composition in Japan - 2010.* Tokyo: Official Gazette Co-operation.
2. Oku T, Yamada K & Kanaya K (2002) Estimation of available energy of dietary fiber in various food materials. *J Japanese Assoc Diet Fiber Res* **6**, 81–86.
3. Knight EL, Stampfer MJ, Hankinson SE, et al. (2003) The impact of protein intake on renal function decline in women with normal renal function or mild renal insufficiency. *Ann Intern Med* **138**, 460–467.
4. De Koning L, Fung TT, Liao X, et al. (2011) Low-carbohydrate diet scores and risk of type 2 diabetes in men. *Am J Clin Nutr* **93**, 1–7.
5. Fung TT, Van Dam RM, Hankinson SE, et al. (2010) Low-carbohydrate diets and all-cause and cause-specific mortality: Two cohort studies. *Ann Intern Med* **153**, 289–298.
6. Lagiou P, Sandin S, Lof M, et al. (2012) Low carbohydrate-high protein diet and incidence of cardiovascular diseases in Swedish women: prospective cohort study. *BMJ* **344**, e4026.
7. Beasley JM, Lacroix AZ, Neuhouser ML, et al. (2010) Protein intake and incident frailty in the women's health initiative observational study. *J Am Geriatr Soc* **58**, 1063–1071.
8. Kobayashi S, Asakura K, Suga H, et al. (2013) High protein intake is associated with low prevalence of frailty among old Japanese women: A multicenter cross-sectional study. *Nutr J* **12**, 164.
9. Kant AK, Graubard BI, Schatzkin A, et al. (1995) Proportion of energy intake from fat and subsequent weight change in the NHANES I epidemiologic follow-up study. *Am J Clin Nutr* **61**, 11–17.
10. Forouhi NG, Sharp SJ, Du H, et al. (2009) Dietary fat intake and subsequent weight change in adults: Results from the European Prospective Investigation into Cancer and Nutrition cohorts. *Am J Clin Nutr* **90**, 1632–1641.
11. Jakobsen MU, O'Reilly EJ, Heitmann BL, et al. (2009) Major types of dietary fat and risk of coronary heart disease: A pooled analysis of 11 cohort studies. *Am J Clin Nutr* **89**, 1425–1432.
12. Risérus U, Willett WC & Hu FB (2009) Dietary fats and prevention of type 2 diabetes. *Prog Lipid Res* **48**, 44–51.
13. Noto H, Goto A, Tsujimoto T, et al. (2013) Low-carbohydrate diets and all-cause mortality: a systematic review and meta-analysis of observational studies. *PLoS One* **8**, e55030.
14. Schulze MB, Schulz M, Heidemann C, et al. (2007) Fiber and magnesium intake and incidence of type 2 diabetes: A prospective study and meta-analysis. *Arch Intern Med* **167**, 956–965.

15. Livesey G, Taylor R, Livesey H, et al. (2013) Is there a dose-response relation of dietary glycemic load to risk of type 2 diabetes? Meta-analysis of prospective cohort studies. *Am J Clin Nutr* **97**, 584–596.
16. Sakurai M, Nakamura K, Miura K, et al. (2012) Dietary glycemic index and risk of type 2 diabetes mellitus in middle-aged Japanese men. *Metabolism* **61**, 47–55.
17. Te Morenga L, Mallard S & Mann J (2012) Dietary sugars and body weight: systematic review and meta-analyses of randomised controlled trials and cohort studies. *BMJ* **346**, e7492–e7492.
18. Malik VS, Pan A, Willett WC, et al. (2013) Sugar-sweetened beverages and weight gain in children and adults: A systematic review and meta-analysis. *Am J Clin Nutr* **98**, 1084–1102.
19. Sluijs I, Beulens JWJ, van der Schouw YT, et al. (2013) Dietary Glycemic Index, Glycemic Load, and Digestible Carbohydrate Intake Are Not Associated with Risk of Type 2 Diabetes in Eight European Countries. *J Nutr* **143**, 93–99.
20. Schwingshackl L & Hoffmann G (2013) Long-term effects of low-fat diets either low or high in protein on cardiovascular and metabolic risk factors : a systematic review and meta-analysis. *Nutr J* **12**, 1–9.
21. Sacks FM, Bray GA, Carey VJ, et al. (2009) Comparison of weight-loss diets with different compositions of fat, protein, and carbohydrates. *N Engl J Med* **360**, 859–73.
22. Brinkworth GD, Noakes M, Parker B, et al. (2004) Long-term effects of advice to consume a high-protein, low-fat diet, rather than a conventional weight-loss diet, in obese adults with Type 2 diabetes: One-year follow-up of a randomised trial. *Diabetologia* **47**, 1677–1686.
23. Wycherley TP, Moran LJ, Clifton PM, et al. (2012) Effects of energy-restricted high-protein, low-fat compared with standard-protein, low-fat diets: A meta-analysis of randomized controlled trials. *Am J Clin Nutr* **96**, 1281–1298.
24. Schwingshackl L & Hoffmann G (2013) Comparison of effects of long-term low-fat vs high-fat diets on blood lipid levels in overweight or obese patients: a systematic review and meta-analysis. *J Acad Nutr Diet* **113**, 1640–61.
25. Hu T, Mills KT, Yao L, et al. (2012) Effects of low-carbohydrate diets versus low-fat diets on metabolic risk factors: a meta-analysis of randomized controlled clinical trials. *Am J Epidemiol* **176 Suppl**, S44-54.
26. Kodama S, Saito K, Tanaka S, et al. (2009) Influence of fat and carbohydrate proportions on the metabolic profile in patients with type 2 diabetes: a meta-analysis. *Diabetes Care* **32**, 959–65.
27. Shai I, Schwarzfuchs D, Henkin Y, et al. (2008) Weight loss with a low-carbohydrate, Mediterranean, or low-fat diet. *N Engl J Med* **359**, 229–41.
28. Hooper L, Abdelhamid A, Moore HJ, et al. (2012) Effect of reducing total fat intake on body weight: systematic review and meta-analysis of randomised controlled trials and

cohort studies. *BMJ* **345**, e7666–e7666.

29. Nordmann AJ, Nordmann A, Briel M, et al. (2006) Effects of low-carbohydrate vs low-fat diets on weight loss and cardiovascular risk factors: a meta-analysis of randomized controlled trials. *Arch Intern Med* **166**, 285–93.
30. Ajala O, English P & Pinkney J (2013) Systematic review and meta-analysis of different dietary approaches to the management of type 2 diabetes. *Am J Clin Nutr* **97**, 505–16. BioMed Central.
31. Santos FL, Esteves SS, da Costa Pereira A, et al. (2012) Systematic review and meta-analysis of clinical trials of the effects of low carbohydrate diets on cardiovascular risk factors. *Obes Rev* **13**, 1048–66.
32. Post RE, Mainous AG, King DE, et al. (2012) Dietary fiber for the treatment of type 2 diabetes mellitus: a meta-analysis. *J Am Board Fam Med* **25**, 16–23.
33. Pedersen AN, Kondrup J & Børsheim E (2013) Health effects of protein intake in healthy adults: a systematic literature review. *Food Nutr Res* **57**, 21245.
34. Walrand S, Short KR, Bigelow ML, et al. (2008) Functional impact of high protein intake on healthy elderly people. *AJP Endocrinol Metab* **295**, E921–E928.