Low carbohydrate diets for people with type 2 diabetes

Adele Mackie

Low carbohydrate diets were once the default method of treatment for diabetes before the development of medications. They have once again emerged as a popular treatment, although there is lack of long-term evidence to support their use. Short-term studies (less than 2 years' duration) have shown that both low carbohydrate and higher carbohydrate diets can be very effective in managing type 2 diabetes and reducing cardiovascular disease risk. Low carbohydrate diets may have some additional advantages over higher carbohydrate/low fat diets, including a more significant reduction in glycaemic variability, medication usage and triglycerides as well as a greater increase in HDL-cholesterol. Studies comparing low carbohydrate to high carbohydrate diets lack a consistent definition, with a range of carbohydrate prescriptions used for each diet arm. There are a range of dietary patterns that can be selected to manage type 2 diabetes and this should be individualised to meet the needs of the person living with diabetes.

The use of low carbohydrate diets to manage type 2 diabetes is not a novel approach. Before the discovery of insulin and oral hypoglycaemic agents, extreme carbohydrate restriction was the default treatment. Dietary advice changed to a focus on reducing fat following increased rates of cardiovascular disease in this population group, and carbohydrate intake was liberalised (Dyson, 2015).

Low carbohydrate diets have recently re-emerged as a popular approach to managing diabetes. However, there are very few large-scale, well-controlled studies that examine the long-term effects of this dietary pattern and there are no studies longer than two years in duration (Shai et al, 2008; Tay et al, 2015a; Dietitians Association of Australia, 2016).

Nutrition therapy recommendations for type 2 diabetes management

Australia currently lacks national evidence-based nutrition guidelines for the management of type 2 diabetes, so diabetes health professionals refer to major guidelines developed internationally. It is generally well recognised that dietary carbohydrate is the main nutrient influencing glycaemic levels after eating (Accurso et al, 2008; Evert et al, 2013). Both the American Diabetes Association (Evert et al, 2013) and Diabetes UK (Diabetes UK, 2011) state that there is insufficient evidence to recommend an ideal amount of carbohydrate, and this should be individualised in consultation with the person who has diabetes.

In terms of preventing chronic disease, the National Health and Medical Research Council (2014) suggests that a carbohydrate intake of 45–65% of total energy consumption may be protective. However, there are no specific recommendations for management of chronic conditions in this same document.

The Dietitians Association of Australia (2016) recognise low carbohydrate diets as a possible therapeutic option, stating that: "Low carbohydrate diets may be an effective option in the non-acute setting for weight loss and improvements in glycaemic control and cardiovascular risk in the short-term, for adults with type 2 diabetes under individualised and ongoing care and assessment by an accredited practising dietitian."

Defining the low-carbohydrate diet

One problem that is encountered when reviewing the evidence on low carbohydrate diets is the

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Article points

1. There are currently no Australian guidelines on carbohydrate requirements for managing type 2 diabetes.
2. Diabetes UK state that there is insufficient evidence to recommend an ideal amount of carbohydrate and this should be individualised in consultation with the person who has diabetes.
3. The National Health and Medical Research Council suggests that a carbohydrate intake of 45–65% of total energy consumption may help prevent chronic disease.

Key words

- Higher carbohydrate diet
- Low carbohydrate diet
- Low fat diet

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Page points

1. Despite claims that low carbohydrate diets are superior for weight loss, several systematic reviews and meta-analyses of low versus high carbohydrate diets have reported there to be no difference in weight loss between the two diet arms at either 3–6 months' and/or 1–2 years' follow-up.
2. A recent, well-designed study supported previous findings that low carbohydrate diets produce much the same weight loss as higher carbohydrate/low fat diets at 1–2 years' follow-up.
3. It can be concluded that low carbohydrate diets are at least as effective for weight loss as low fat diets, but they are not superior.

lack of a consistent definition. Many studies have been published citing a range of carbohydrate prescriptions for the low carbohydrate intervention, from 20 g of carbohydrate per day up to 45% of total energy intake from carbohydrate (Feinman, 2008; Shai et al, 2008; Hu et al, 2012; Ajala et al, 2013; Feinman, 2015).

A recent systematic review and meta-analysis by Snorgaard et al (2017) found a wide variance in reported carbohydrate intake between low carbohydrate and high carbohydrate groups, with low carbohydrate groups consuming 57–198 g and the high carbohydrate groups consuming 133–205 g of carbohydrate daily. This obviously makes it very difficult to compare results across different studies. *Table 1* lists the most common definitions of carbohydrate intake cited in the literature.

Evidence for low carbohydrate diets

Studies investigating low carbohydrate diets replace some of the carbohydrate with a higher intake of fat or protein or both. They are compared to a control diet that is higher in carbohydrate and lower in fat (Shai et al, 2008; Elhayany et al, 2010; Ajala et al, 2013).

Outcomes measures of most studies have focused on weight management, glycaemic control and cardiovascular disease risk.

Weight management

Low carbohydrate advocates often make strong claims about this particular dietary pattern being superior for weight loss. Despite these claims, several systematic reviews and meta-analyses of low versus high carbohydrate diets have reported there to be no difference in weight loss between the two diet arms at either 3–6 months' and/or 1–2 years' follow-up (Hu et al, 2014; Naude et al, 2014; Dyson et al, 2015; Snorgaard et al, 2017). These findings support the principle of energy balance and a sustained energy deficit resulting in weight loss, irrespective of macronutrient composition (Naude et al, 2014).

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) have recently completed one of the most well designed studies looking at the effects of an isocaloric low carbohydrate/high unsaturated fat diet compared to a higher carbohydrate (low glycaemic index)/low fat diet on 115 people with type 2 diabetes. The findings from this larger scale study support previous findings that low carbohydrate diets produce much the same weight loss as higher carbohydrate/low fat diets at 1–2 years' follow-up, with both groups achieving a mean weight loss of 9.1% (Tay et al, 2015a).

Therefore, it can be concluded that low carbohydrate diets are at least as effective for weight loss as low fat diets, but they are not superior (Feinman, 2008; Elhayany, 2010; Naude et al, 2014; Tay et al, 2014; 2015a; Dyson, 2015; Snorgaard et al, 2017).

Optimising glycaemic management

The effect of low carbohydrate diets on glycaemic levels has been variable. Whilst the reviews by Ajala et al (2013) and Snorgaard et al (2017) have reported a slightly greater short-term reduction in HbA_{1c} (at 3–6 months) when following a low

Table 1. The most common definitions of carbohydrate intake (Feinman 2008; Shai et al, 2008; Dyson, 2015; Noakes and Windt, 2016).

High carbohydrate	>230 g of carbohydrate daily or >45% of energy.
Moderate carbohydrate	130–230 g of carbohydrate daily or 26–45% of total energy.
Low carbohydrate	50–130 g of carbohydrate daily or 10–26% of total energy.
Very low carbohydrate, high fat (ketogenic)	20–50 g of carbohydrate daily or <10% of total energy.
Australian Nutrient Reference Values (National Health and Medical Research Council, 2014) NB These guidelines are for chronic disease prevention, not for diabetes management.	45–65% of total energy. This equates to 230–310 g of carbohydrate per day for an average energy intake of 8700 kJ.

carbohydrate diet, the evidence is not strong due to heterogeneity between studies. The review by Naude et al (2014) found no difference at all. Dyson (2015) reported mixed results with three studies showing a significant reduction in HbA_{1c} in the short-term (i.e. less than 1 year) and four studies showing no significant difference. Any reduction in HbA_{1c} that is obtained at 3–6 months with the low carbohydrate diet appears to be lost at 12 months or more, with both low and high carbohydrate groups obtaining a similar HbA_{1c} at this time point (Dyson, 2015; Snorgaard et al, 2017).

The data from Tay et al (2014; 2015a) support these findings, as they showed that those following the low carbohydrate diet achieved a greater reduction in $HbA_{1c.}$ However, this only occurred in people who had a baseline HbA_{1c} of >62 mmol/mol (>7.8%) and was not sustained at 12 months. Both the low carbohydrate and the high carbohydrate groups achieved a mean reduction in HbA_{1c} of 11 mmol/mol (1.0%).

Although there was no difference in HbA_{1c} between the two diet arms of this study, glycaemic variability was reduced in the low carbohydrate group. Participants on the low carbohydrate diet were 85% more likely to spend time in the euglycaemic range, 56% less likely to spend time in the hyperglycaemic range and 16% less likely to spend time in the hypoglycaemic range (Tay et al, 2014; 2015a). As glycaemic variability is emerging as an independent risk factor for diabetes related complications (Tay et al, 2015a; 2015b), this could be an important finding.

An additional consideration is that participants following the low carbohydrate diet also experienced a two-fold greater reduction in their diabetes medications compared to those following the higher carbohydrate, low fat diet (Tay et al, 2014; 2015a).

Cardiovascular disease risk

Both low carbohydrate and higher carbohydrate diets have been shown to effectively reduce cardiovascular disease risk by lowering weight, total cholesterol, LDL-cholesterol, blood pressure and triglycerides, as well as increasing HDL-cholesterol. However, it appears from the literature that low carbohydrate diets that are also high in unsaturated fats (rather than saturated fats) have an additional benefit, showing a more significant reduction in triglycerides and increased HDL-cholesterol compared to higher carbohydrate, lower fat diets (Shai et al, 2008; Elhayany et al, 2010; Hu et al, 2012; Tay et al 2014; 2015a).

It should be noted, however, that many of the dietary interventions in this field implement a low carbohydrate, higher saturated fat diet. In these studies, participants have shown an increase in LDL-cholesterol (Hu et al, 2012; Noakes and Windt, 2016). Furthermore, there is also evidence that saturated fats worsen insulin resistance whilst mono-unsaturated and poly-unsaturated fats improve insulin sensitivity, lipid profiles and blood pressure, independent of body weight (Riccardi et al, 2004).

Comparison to other dietary approaches

Ajala et al (2013) undertook a systematic review and meta-analysis of 20 randomised controlled trials looking at seven different diets followed from 6 months to 4 years. They found that a low carbohydrate, low glycaemic index (GI), Mediterranean and high protein diet were all effective at reducing HbA_{1c} by 1.3–5.5 mmol/mol (0.12–0.5%) compared with a low fat, higher carbohydrate diet (50–60% energy intake from carbohydrate). The Mediterranean diet produced the greatest reduction.

Furthermore, the low carbohydrate, low GI and Mediterranean diets all led to significant improvements in lipid profiles with the low carbohydrate diet showing a more significant increase in HDL-cholesterol (Ajala et al, 2013). *Table 2* outlines the carbohydrate content of each dietary intervention.

Following and maintaining a low carbohydrate diet

Whilst low carbohydrate diets may be one viable option to help manage diabetes, are people actually able to sustain them? Tay et al (2015a) found that after one year of their two-year intervention, reported carbohydrate intake increased from the prescribed 50 g per day to about 70 g per day.

The review and meta-analysis by Snorgaard et

Page points

1. Results from studies on the effect of low carbohydrate diets on glycaemic levels have varied. Glycaemic improvements seen early on appear to be lost at 12 months or more.
2. Both low carbohydrate and higher carbohydrate diets have been shown to effectively reduce cardiovascular disease risk by lowering a number of risk factors.
3. A systematic review of seven different diets found that low carbohydrate, low glycaemic index, Mediterranean and high protein diets were all effective at reducing HbA_{1c} compared with a low fat, higher carbohydrate diet.

Page points

1. Regular and ongoing support from health professionals to implement diet and lifestyle change is important if study results are to be replicated in the "real world".
1. A low carbohydrate diet is clinically inappropriate for certain groups of people. Anyone wanting to follow a low carbohydrate diet should be properly assessed for suitability by their diabetes team, including an accredited practising dietitian.
2. Hypoglycaemia may be an immediate side effect of low carbohydrate diets in people with diabetes who are using insulin or certain oral hypoglycaemic agents.
4. For anyone contemplating a reduction in their carbohydrate intake, it is imperative that this is done in conjunction with input from their entire diabetes team, and include a medication review.

Table 2. Carbohydrate content of diet interventions (Ajala et al, 2013).

Dietary intervention	Average carbohydrate content
Low carbohydrate*	13–45% 20–60 g
Low glycaemic index	37–50%
Mediterranean diet	50%
High protein	40–45%

* Some studies listed as percentage of energy intake and other studies listed as total grams per day.

al (2017) found that carbohydrate intake among low carbohydrate interventions increased from an average prescription of 25% energy intake to 30% at 3–6 months and to 38% at one year with further increases in studies lasting longer than 12 months.

Participants in the study conducted by Tay et al (2014; 2015a) also received fortnightly dietary counselling for the first 12 weeks and then monthly thereafter. In addition, they were supplied key foods from their dietary intervention for the first 12 weeks and then either key foods or an $50 food voucher on alternate months thereafter. Furthermore, all participants undertook free, supervised 60-minute exercise classes three days per week for the duration of the study.

The level of support provided to these participants is a significant aspect of the intervention, and it would be difficult to replicate in the "real world". It highlights the importance and impact of regular and ongoing support from health professionals to implement not just the low carbohydrate diet, but any diet or lifestyle change. The significant positive results achieved by both the low and high carbohydrate arms in this study further demonstrate that people with diabetes should have access to ongoing multidisciplinary care.

Are low carbohydrate diets appropriate for everyone?

Low carbohydrate diets are simply one of many dietary approaches that can be used to manage diabetes. However, due to the restrictive nature of this diet, there is a high risk of suboptimal kilojoule (kJ) and nutrient intake if the diet is not well planned (Calton, 2010; Gardner, 2010). This makes the diet clinically inappropriate for certain groups of people, such as:

- Somebody with an active or past history of eating disorders/disordered eating.
- Somebody with active cancer.
- Somebody who is malnourished or in a state of catabolism or renal failure.
- Anyone at risk of malnutrition, such as an elderly person with type 2 diabetes.
- Children, due to the possible impact on growth.

People with diabetes who are keen to follow a low carbohydrate diet should be properly assessed for suitability by their diabetes team, including an accredited practising dietitian.

Potential side effects and risks of a low carbohydrate diet

Hypoglycaemia may be an immediate side effect of low carbohydrate diets in people with diabetes who are using insulin or certain oral hypoglycaemic agents. For anyone contemplating a reduction in their carbohydrate intake, it is imperative that this is done in conjunction with input from their entire diabetes team, and include a medication review. Patients will need to have their diabetes medications reduced or ceased prior to changing their diet (Feinman et al, 2008; Dyson, 2015; Feinman et al, 2015).

A low carbohydrate diet needs to be well planned to ensure that it is nutritionally adequate. Fibre is the main nutrient of concern when considering the foods often significantly reduced when adopting a low carbohydrate diet. Studies looking at the nutrient intakes of popular

diets, in particular the low carbohydrate/high fat Atkins diet, have shown that it is often deficient in a number of nutrients including dietary fibre, vitamin C, folic acid, B-group vitamins (thiamine, pantothenic acid and biotin), vitamin E, potassium and calcium (Calton, 2010; Gardner, 2010). Tay et al (2014; 2015a) showed that a carefully planned low carbohydrate diet can still meet the requirements for fibre, dairy and micronutrients; however, it is known that many popular low carbohydrate diets are not as carefully planned and nutritionally balanced (Calton, 2010; Gardner, 2010). *Table 3* provides an outline of a nutritionally balanced, low carbohydrate diet.

Noakes and Windt (2016) have reported that people may experience headache, fatigue and muscle cramping during the initial stage of implementing the low carbohydrate diet. However, the symptoms are often transient and subside when fat adaption occurs.

As there are no studies reported in the literature extending beyond two years in duration, the long-term risks and outcomes of a low carbohydrate diet are not known (Dietitians Association of Australia, 2016).

The state of Australia's current diet

The latest National Nutrition Survey (NNS) showed that Australians are currently consuming about 45% of total energy from carbohydrate (Australian Bureau of Statistics, 2015), which is at the lower end of the guidelines for chronic disease prevention. Alarmingly, the same survey highlighted that 35% of total energy intake is from discretionary foods such as cakes, muffins, scones, desserts, cereal bars, sweet and savoury biscuits and sweetened drinks – many of which are significant sources of carbohydrate. Fewer than 7% of people are meeting the recommendations for vegetables (Australian Bureau of Statistics, 2015). There is no reason to believe that people with type 2 diabetes do not follow a similar dietary pattern.

Given these statistics, it may be prudent to encourage people with type 2 diabetes to reduce their intake of discretionary foods and increase their intake of vegetables before looking to reduce the carbohydrate in their diet. Based on average nutrient intake data recently obtained from NNS, a daily reduction of approximately 70 g of carbohydrate can be achieved if people >19 years of age were to reduce their intake of discretionary foods to less than the recommended 600-kJ portion size (National Health and Medical Research Council, 2013; Australian Bureau of Statistics, 2015). Addressing the overall quality of the diet, rather than focusing on individual macronutrients may result in greater health benefits than just improving blood glucose levels.

Conclusion

Many dietary patterns have been shown to effectively reduce weight, manage glycaemia and reduce cardiovascular disease risk in people with type 2 diabetes. A low carbohydrate diet is one dietary option, and recent evidence indicates that a well-planned low carbohydrate diet that is also low in saturated fat/higher in unsaturated fat may have some additional benefits for increasing HDL-cholesterol and lowering triglycerides, medication usage and glycaemic variability. However, this dietary approach is not clinically or socially appropriate for everyone. When choosing a dietary approach to manage diabetes, it needs

Table 3. A balanced approach to low-carbohydrate eating (Tay et al, 2014; 2015).

This suggested meal plan provides approximately 70 g of carbohydrate.

Breakfast	30 g high fibre, low glycaemic index cereal + 100 g reduced fat Greek yoghurt or milk
Lunch	100 g baked salmon, 1–2 cups of salad vegetables, 40 g avocado, 1 tablespoon olive oil with balsamic vinegar
Dinner	150–200 g of lean red meat/chicken/fish + 100 g baked pumpkin + 100 g mixed low-starch vegetables (bok choy, broccoli, zucchini, etc) + 20 g parmesan cheese
Snacks	40 g almonds + 200 g strawberries + 1 small coffee with reduced fat milk

Page points

1. A carefully planned low carbohydrate diet can meet the requirements for fibre, dairy and micronutrients.
2. While Australians are currently consuming about 45% of total energy from carbohydrate, 35% of energy intake is from discretionary foods. Encouraging those with type 2 diabetes to reduce such foods and to increase their intake of vegetables may be prudent.
3. As well as reducing weight, managing glycaemia and reducing cardiovascular risk in people with type 2 diabetes, a well-planned low carbohydrate diet that is low in saturated fat/higher in unsaturated fat may have some additional benefits.

"Ongoing and intensive multidisciplinary support is crucial for sustainable lifestyle change, irrespective of the dietary approach."

to be decided on in conjunction with the person with diabetes. It needs to be individualised and suitable for them in terms of ease of adherence, availability and affordability of foods, as well as social and cultural acceptability. What is clear from the evidence is that ongoing and intensive multidisciplinary support is crucial for sustainable lifestyle change, irrespective of the dietary approach. ■

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