An introduction to carbohydrate counting in type 1 diabetes

Alison Edwards

A great deal has been written on the benefits to be gained from carbohydrate counting by people with type 1 diabetes, but what exactly is this skill? When it comes down to it, how can we best help people with diabetes as they try to make sense of food labels or estimate how much carbohydrate they have on their plate for dinner? This article provides a brief overview of how our knowledge of carbohydrate and diabetes has evolved over time, moving from carbohydrate restriction and exchanges into the practice of carbohydrate counting. It describes one approach to making individual calculations, with a worked example and some practical resources, including examples of how carbohydrate counting has been a help to some of my patients with type 1 diabetes.

Before the discovery of insulin in 1921, the controlled intake of food (carbohydrates) was the only known means of regulating blood glucose levels (Franz, 2004). Indeed, Robert Daniel Lawrence, the British physician who was an early recipient of insulin injections, was put onto the Allen dietary treatment of "absolute starvation" (Hill and Eckman, 1915; *Box 1*), with the predicted lifespan on this treatment being 3–4 years (Joslin, 1917), before he was treated with insulin.

Around this time, Joslin (1927) was researching the effects of dextrose and starches on blood glucose. As Franz (2004) notes,

> *"The physician issued the order and the dietitian developed an 'ideal' meal plan; the 'patient' received instructions on how to comply with the doctor's orders."*

Restricting carbohydrate consumption continued up until the 1990s. If people with diabetes reported they were hungry, they were told to eat cheese or meat as snacks – foods that were carbohydrate-free but contributed extra fat and calories to their diet. Up until 1994, nutritional recommendations for people with diabetes attempted to define an ideal nutritional prescription that would apply to nearly everyone with the condition (Franz, 2004). Thus, ideal percentages of energy obtained from carbohydrate, protein and fat were recommended. Historically, the use of carbohydrate exchanges (now referred to as counting or estimation) was a restrictive process to eliminate the variance in blood glucose levels created by irregular eating, which could not be managed with biphasic (mixed) insulin (Oliver, 2008). We now know there is no evidence for a recommended ideal amount of carbohydrate

Box 1. The Allen "absolute starvation" diet (Hill and Eckman, 1915)

Waking:	Cocoa, one egg
Breakfast:	Black coffee, whiskey
Lunch:	Green salad, one egg
Tea:	Cup of tea
Supper:	Green salad

Citation: Edwards A (2015) An introduction to carbohydrate counting in type 1 diabetes. *Journal of Diabetes Nursing* **19**: 73–7

Article points

1. Carbohydrate counting is a meal-planning approach to managing type 1 diabetes that focuses on the total amount of carbohydrate eaten at meals and in snacks, on the basis of which bolus insulin doses can be adjusted.
2. By performing a series of three calculations to determine the total daily dose of insulin, the insulin-to-carbohydrate ratio and the insulin sensitivity factor, people with diabetes can be taught a simple algorithm to adjust their bolus insulin dose according to the amount of carbohydrate consumed.
3. Group education sessions are useful for training people with diabetes in carbohydrate counting, allowing practical learning in a safe, supportive environment.

Key words

- Carbohydrate counting
- Type 1 diabetes

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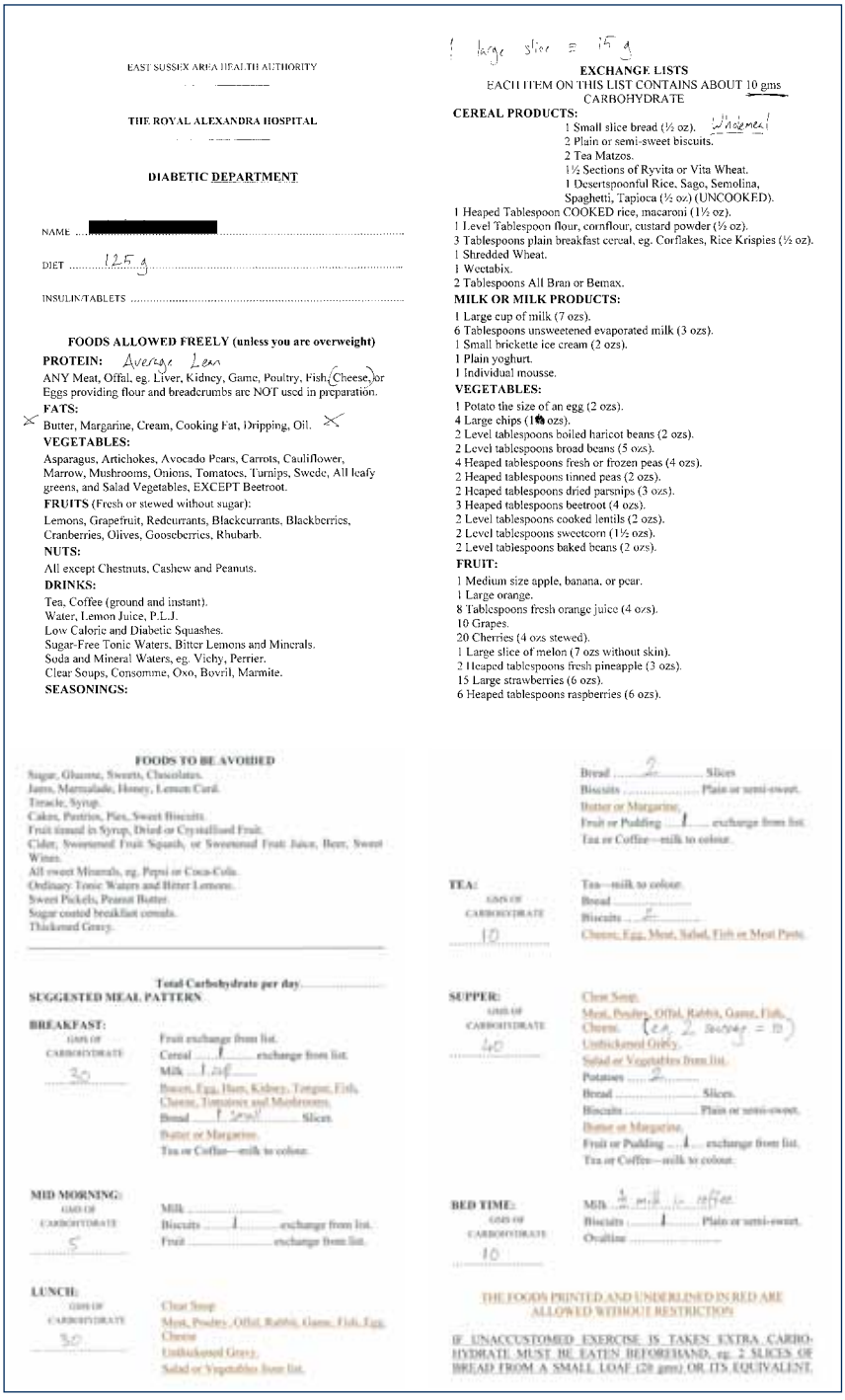

EAST SUSSEX AREA HEALTH AUTHORITY

THE ROYAL ALEXANDRA HOSPITAL

DIABETIC DEPARTMENT

NAME [redacted]

DIET 125 g

INSULIN/TABLETS

FOODS ALLOWED FREELY (unless you are overweight)

PROTEIN: Average Lean
ANY Meat, Offal, eg. Liver, Kidney, Game, Poultry, Fish, Cheese, or Eggs providing flour and breadcrumbs are NOT used in preparation.

FATS:
Butter, Margarine, Cream, Cooking Fat, Dripping, Oil.

VEGETABLES:
Asparagus, Artichokes, Avocado Pears, Carrots, Cauliflower, Marrow, Mushrooms, Onions, Tomatoes, Turnips, Swede, All leafy greens, and Salad Vegetables, EXCEPT Beetroot.

FRUITS (Fresh or stewed without sugar):
Lemons, Grapefruit, Redcurrants, Blackcurrants, Blackberries, Cranberries, Olives, Gooseberries, Rhubarb.

NUTS:
All except Chestnuts, Cashew and Peanuts.

DRINKS:
Tea, Coffee (ground and instant).
Water, Lemon Juice, P.L.J.
Low Caloric and Diabetic Squashes.
Sugar-Free Tonic Waters, Bitter Lemons and Minerals.
Soda and Mineral Waters, eg. Vichy, Perrier.
Clear Soups, Consomme, Oxo, Bovril, Marmite.

SEASONINGS:

1 large slice = 15 g

EXCHANGE LISTS
EACH ITEM ON THIS LIST CONTAINS ABOUT 10 gms CARBOHYDRATE

CEREAL PRODUCTS:
1 Small slice bread (½ oz). Wholemeal
2 Plain or semi-sweet biscuits.
2 Tea Matzos.
1½ Sections of Ryvita or Vita Wheat.
1 Desertspoonful Rice, Sago, Semolina, Spaghetti, Tapioca (½ oz) (UNCOOKED).
1 Heaped Tablespoon COOKED rice, macaroni (1½ oz).
1 Level Tablespoon flour, cornflour, custard powder (½ oz).
3 Tablespoons plain breakfast cereal, eg. Corflakes, Rice Krispies (½ oz).
1 Shredded Wheat.
1 Weetabix.
2 Tablespoons All Bran or Bemax.

MILK OR MILK PRODUCTS:
1 Large cup of milk (7 ozs).
6 Tablespoons unsweetened evaporated milk (3 ozs).
1 Small brickette ice cream (2 ozs).
1 Plain yoghurt.
1 Individual mousse.

VEGETABLES:
1 Potato the size of an egg (2 ozs).
4 Large chips (1½ ozs).
2 Level tablespoons boiled haricot beans (2 ozs).
2 Level tablespoons broad beans (5 ozs).
4 Heaped tablespoons fresh or frozen peas (4 ozs).
2 Heaped tablespoons tinned peas (2 ozs).
2 Heaped tablespoons dried parsnips (3 ozs).
3 Heaped tablespoons beetroot (4 ozs).
2 Level tablespoons cooked lentils (2 ozs).
2 Level tablespoons sweetcorn (1½ ozs).
2 Level tablespoons baked beans (2 ozs).

FRUIT:
1 Medium size apple, banana, or pear.
1 Large orange.
8 Tablespoons fresh orange juice (4 ozs).
10 Grapes.
20 Cherries (4 ozs stewed).
1 Large slice of melon (7 ozs without skin).
2 Heaped tablespoons fresh pineapple (3 ozs).
15 Large strawberries (6 ozs).
6 Heaped tablespoons raspberries (6 ozs).

FOODS TO BE AVOIDED
Sugar, Glucose, Sweets, Chocolates.
Jams, Marmalade, Honey, Lemon Curd.
Treacle, Syrup.
Cakes, Pastries, Pies, Sweet Biscuits.
Fruit tinned in Syrup, Dried or Crystallised Fruit.
Cider, Sweetened Fruit Squash, or Sweetened Fruit Juice, Beer, Sweet Wines.
All sweet Minerals, eg. Pepsi or Coca-Cola.
Ordinary Tonic Waters and Bitter Lemons.
Sweet Pickels, Peanut Butter.
Sugar coated breakfast cereals.
Thickened Gravy.

Total Carbohydrate per day

SUGGESTED MEAL PATTERN

BREAKFAST: GMS OF CARBOHYDRATE 30
Fruit exchange from list.
Cereal 1 exchange from list.
Milk 1 pint
Bacon, Egg, Ham, Kidney, Tongue, Fish, Cheese, Tomatoes and Mushrooms.
Bread 1 small Slices.
Butter or Margarine.
Tea or Coffee—milk to colour.

MID MORNING: GMS OF CARBOHYDRATE 5
Milk
Biscuits 1 exchange from list.
Fruit exchange from list.

LUNCH: GMS OF CARBOHYDRATE 30
Clear Soup
Meat, Poultry, Offal, Rabbit, Game, Fish, Egg
Cheese
Unthickened Gravy.
Salad or Vegetables from list.

Bread 2 Slices
Biscuits Plain or semi-sweet.
Butter or Margarine.
Fruit or Pudding 1 exchange from list.
Tea or Coffee—milk to colour.

TEA: GMS OF CARBOHYDRATE 10
Tea—milk to colour.
Bread
Biscuits 2
Cheese, Egg, Meat, Salad, Fish or Meat Paste.

SUPPER: GMS OF CARBOHYDRATE 40
Clear Soup.
Meat, Poultry, Offal, Rabbit, Game, Fish, Cheese. (ca. 2 tablespoons = 10)
Unthickened Gravy.
Salad or Vegetables from list.
Potatoes 2
Bread Slices.
Biscuits Plain or semi-sweet.
Butter or Margarine.
Fruit or Pudding 1 exchange from list.
Tea or Coffee—milk to colour.

BED TIME: GMS OF CARBOHYDRATE 10
Milk ½ pint in coffee
Biscuits 1 Plain or semi-sweet.
Ovaltine

THE FOODS PRINTED AND UNDERLINED IN RED ARE ALLOWED WITHOUT RESTRICTION

IF UNACCUSTOMED EXERCISE IS TAKEN EXTRA CARBOHYDRATE MUST BE EATEN BEFOREHAND, eg. 2 SLICES OF BREAD FROM A SMALL LOAF (20 gms) OR ITS EQUIVALENT.

Figure 1. Sample exchange list from the 1980s. Reproduced from the East Sussex Area Health Authority.

for maintaining long-term glycaemic control in people with type 1 diabetes (Dyson et al, 2011).

The 10-g carbohydrate exchange lists used in the 1980s were prescriptive and limited total carbohydrate intake. In the example in *Figure 1*, a current patient of mine, Vicci, was allowed 125 g of total carbohydrate each day, meaning she could pick 12.5 exchanges from the list provided. This would be distributed throughout the day as three meals and three snacks to match the inflexible twice-daily biphasic insulin injections. Missing these prescribed snacks meant that a hypoglycaemic episode was almost guaranteed.

Indeed, the advice within other diet sheets published at the time, such as the North Warwickshire Health Authority's *Diet Information for Insulin-Dependent Diabetics*, was clear:

> *"There are three rules for diabetics:*
>
> 1. *Eat your meals regularly.*
> 2. *Avoid sugar and sugary foods.*
> 3. *Eat a controlled amount of carbohydrate to balance your dose of insulin."*

Modern-day carbohydrate counting

Carbohydrate is the main nutritional consideration for glycaemic control in individuals with type 1 diabetes, and both the amount and the type of carbohydrate have an effect on post-prandial blood glucose levels (Dyson et al, 2011).

Carbohydrate counting is a meal-planning approach used to manage diabetes that focuses on the total amount of carbohydrate eaten at meals and in snacks (Gillespie et al, 1998). Taking a greater bolus insulin dose when eating a meal with more carbohydrate makes perfect sense, and most people with type 1 diabetes use this approach every day, based on their experience with the condition. Carbohydrate counting skills enable individuals to assess the impact of different meals on blood glucose levels and their resultant bolus insulin requirements. For example, a perceived "big" meal such as a roast dinner (in which there is lots of food on the plate but in which potatoes and Yorkshire pudding make up the only carbohydrate) may contain half the carbohydrate of a meal such as spaghetti bolognaise.

Randomised controlled trials have shown that carbohydrate counting can improve glycaemic control and quality of life without increasing the risk of severe hypoglycaemia, weight gain or increases in blood lipid levels (Diabetes Control and Complications Trial Research Group, 1993).

Carbohydrate counting and insulin adjustment have been shown to be beneficial and cost-effective over the long term (Speight et al, 2007).

To teach the skills needed to carbohydrate count, it is vital to go back to basics and identify all foods that contain carbohydrate; doing this by performing your own research reading the information on that "meal deal" you bought for lunch is helpful. Food labels and packets have lots of information on them, so it is useful to have some handy to show people in clinic. For many of us, breakfast and lunch tend to be quite similar from day to day; indeed, many people are happy to eat the same breakfast every day.

People with any type of diabetes would benefit from becoming "carbohydrate aware," taking note of the total carbohydrate levels displayed on the back of packets. Note that the front of food packaging will only provide information about the "of which sugars" carbohydrate value, whereas the value that is needed – total carbohydrate – will be found on the reverse in the more detailed nutritional information. Examples of common misconceptions are that potatoes are a vegetable, and so do not count, and that fruits are calorie- and carbohydrate-free.

As a dietitian, I sometimes teach carbohydrate counting on a one-to-one basis or conduct a joint appointment with our DSN; however, the teaching appears to be most effective when we hold group education sessions, with time for reflection and personal learning. People report that they react to each blood glucose level in the "here and now," not having the time to reflect on whatever trends may be occurring in their blood glucose levels. Reviewing these results in a group situation presents a huge learning opportunity, for group members and healthcare professionals alike, as the social learning theory (Bandura, 1977) suggests that people learn by observing, imitating and modelling from each other.

Since 13 December 2014, new food labels suggest an average healthy adult can consume a Reference Intake (RI; replaces Guideline Daily Amount) of 260 g of total carbohydrate per day (based on an average adult consuming 2000 kcal/day). Note that the RI is not a target, just a reference. Our goal is neither to encourage people with type 1 diabetes to eat more carbohydrate nor to suggest unnecessary restriction; rather, it is to suggest that they can eat any type of carbohydrate as long as it can be accurately recorded and the correct amount of bolus insulin administered. Carbohydrate intake varies greatly depending on activity levels, body size and food preferences, to name just a few influences. In a recent type 1 diabetes education group I ran with six people, the variation was huge: from 90 g to 350 g of total carbohydrate in 1 day.

The calculations

When teaching in our clinic, we have chosen the method whereby one unit of bolus insulin is given for a calculated amount of carbohydrate, measured in grams.

Step 1: Total daily dose

The first step is to calculate the total daily dose (TDD); that is, the basal and bolus insulin doses added together. An average figure taken from the past 3 days is most useful.

To calculate the total daily dose (TDD):

Add together the bolus insulin taken in a day.
For example:

Breakfast:	8 units +
Lunch:	10 units +
Dinner:	12 units
Total bolus =	**30 units**

Add this to the daily basal insulin dose. For example:

Bolus insulin =	30 units +
Basal insulin =	20 units
TDD =	**50 units**

The worked example above shows the details and, while it is not something that we need to do with all of our type 1 patients, it gives an understanding of the process. However, the 2011 Skills for Life survey revealed that 49.1% of adults in the UK (16.8 million) have numeracy skills equivalent to a 9–11-year-old child (Department for Business Innovation & Skills, 2012), and the potential for panic or anxiety when discussing maths in a group is something we need to be aware of and sensitive to. Giving worked examples and encouraging group members who are more confident to help others is a useful strategy.

Page points

1. People with all types of diabetes would benefit from being "carbohydrate aware" and can use the information provided on food packaging to determine the amount of carbohydrate.
2. Clinicians need not aim to increase or restrict carbohydrate consumption; rather, they should inform people with diabetes that they can eat any type of carbohydrate as long as it is accurately recorded.
3. The total daily dose and 500 and 100 rules are simple calculations that can be used to determine the amount of bolus insulin to administer in response to carbohydrate intake.

Box 2. Case report: Louise.

Louise has had type 1 diabetes for 20 years. On a recent course, she found learning about the insulin sensitivity factor/correction dose particularly useful. As a member of a Quality & Regulatory team, her job often found her travelling and working in environments that would not easily allow her to frequently test her blood glucose. To work around this, she tended to graze throughout the day. Now, using a blood glucose meter, she is able to correct blood glucose levels to within her target range: 1 unit of bolus insulin reduces her blood glucose level by 2.5 mmol/L. Louise is more confident and more in control of her diabetes whilst still avoiding hypoglycaemia, which used to affect her performance and got in the way of life.

Step 2: The 500 and 100 rules

The next step is to use the TDD in the "500 rule" and the "100 rule" (King and Armstrong, 2007; Davidson et al, 2008). In my experience, giving people ratios to use as a starting point and then discussing the maths at a later meeting has been more successful.

The 500 rule to calculate the insulin-to-carbohydrate ratio:

1 unit of bolus insulin covers:
500 ÷ TDD = __ g of carbohydrate

For example, 1 unit of bolus insulin covers
500 ÷ 50 = 10 g of carbohydrate

In this example, this means that 1 unit of bolus insulin will cover 10 g of carbohydrate consumed. So, if eating four crumpets with butter (80 g total carbohydrate), use 80 ÷ 10 = 8 units. Whereas, if eating two breakfast wheat biscuits with 200 mL milk (40 g total carbohydrate), use 40 ÷ 10 = 4 units.

Among different individuals, the doses of insulin (and therefore the TDD) will vary greatly depending on their body size, activity levels and duration of type 1 diabetes, so the insulin-to-carbohydrate ratios in a single group could vary greatly – in my experience, from 1 unit per 3 g carbohydrate up to 1 unit per 21 g carbohydrate within a group of eight people.

Using the 100 rule, we can calculate the insulin sensitivity factor (ISF; also known as the correction dose). The example below shows that 1 unit of bolus insulin lowers blood glucose by 2 mmol/L when the TDD is 50 units.

The 100 rule to calculate the insulin sensitivity factor/correction dose:

1 unit of bolus insulin will lower blood glucose by
100 ÷ TDD = __ mmol/L

For example, 1 unit of bolus insulin will lower blood glucose by 100 ÷ 50 = 2 mmol/L

Blood glucose meters offering bolus advice are available in the form of the Accu-Chek® Aviva Expert (Roche Diagnostics, Burgess Hill) or the FreeStyle® InsuLinx meter (Abbott, Maidenhead). These can be a real help in giving people more confidence, as they do the maths while allowing individuals the autonomy to review the dose suggested. It is always necessary to count the total carbohydrate in a meal, after which blood glucose is measured and the amount of carbohydrate to be eaten is entered, and the meter advises how much bolus insulin is required. This suggests an insulin dose both for the carbohydrate and to determine how much insulin could also be added for the ISF to bring blood glucose into the range set on the meter. The meters are set up individually so that people can agree their own goals. The experience of one of my patients with one of these meters is described in *Box 2*.

Practical tips on educating people with diabetes

The Dose Adjustment for Normal Eating (DAFNE) programme originated in Germany and has been running there since the 1980s, first coming to our shores in the early 2000s (DAFNE Study Group, 2002). This structure was then adapted by the Bournemouth Diabetes and Endocrine Centre team, who introduced the Bournemouth Type 1 Intensive Education (BERTIE) model (Everett, 2003). After training in BERTIE, our team now delivers its own version of the course to groups of eight participants with type 1 diabetes, a DSN and a diabetes specialist dietitian. Across the UK, 84 centres in the Diabetes Education Network run their own type 1 diabetes education programmes. Our course runs over four successive weeks, allowing a week between each session for practical learning from the 21 meals (plus snacks) that will be eaten throughout the 7 days, and possibly some exercise.

Eating lunch together in a group over these successive weeks is a useful and safe way to learn, allowing group members to help each other out with the sums. This has also highlighted the fact that some supermarkets do not label their pre-packed sandwiches with the total carbohydrate values per pack, they are only listed per 100g. One solution to this is to weigh the sandwiches and make a calculation. However, while scales are freely available in this learning environment, they are not so common in the "real world." An alternative approach is to estimate

the carbohydrate values of the bread and then identifying other carbohydrate sources, such as pickle, in that sandwich. By weighing a chocolate crispy cake or tiny muffin, we can get around the fact that fresh bakery items are currently exempt from nutrition labelling. One such experience that occurred in one of our education sessions is described in *Box 3*.

Taking photos of actual dinners is helpful in teaching this concept – some people are happy to share their own photos for this exercise; otherwise, they have the pleasure of looking at what is eaten in my household.

Conclusion

Carbohydrate counting is a proven and robust method to help manage type 1 diabetes and I hope that this article has given a clearer understanding of what it is and how it can work for the people with diabetes that we work with. Using the resources that are now available will help the process. As with all new skills, it will take some time to implement, but seeing the results in improved confidence among people who are more in control of their eating and diabetes is worth the extra work. ■

Helpful resources

- The Bournemouth Diabetes and Endocrine Centre has an excellent website that takes you through the carbohydrate counting process, and is useful for both people and healthcare providers (available at: www.bdec-e-learning.com).
- The Diabetes UK *Carbs Count* resource is available to download for free from the Diabetes UK shop (available at: http://bit.ly/1DFRXe8), and takes you through the process with worked examples.
- The Diabetes Education Network (available at: www.diabetes-education.net) offers support and resources allowing diabetes teams to provide high-quality self-management education for their patients. The *Type 1 Diabetes Workbook* (available at: http://bit.ly/1xYmxRC) is an invaluable part of all our locally run sessions.
- Other resources to help with carbohydrate counting can be found at the Carbs & Cals website (available at: www.carbsandcals.com), which allows you to "eyeball" a portion of carbohydrate on a plate, from over 3500 photos. This resource is available as a book or as an app for Android and iOS devices.
- For home-cooked recipes, the Cook and Count app (available at: www.healthapps.uk.com) allows you to build your own recipes from a list of 2000 ingredients, divide into portions and see the carbohydrate content of each portion. You can create your own digital recipe file, upload photos and share via social media.

Acknowledgements

Thank you to Vicci, Louise and Sarah for giving permission for me to share some of their stories.

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Box 3. Case report: Sarah.

In one of our education groups we met Sarah, who liked baking. She produced a fabulous Victoria sponge at one session and calculated herself the total carbohydrate content of the whole cake from the flour, sugar, buttercream and jam used, then divided it by the number of slices, determining 75 g of total carbohydrate per portion. Two hours after eating and then dosing with the bolus insulin to cover this 75 g, every group member had a blood glucose level below 9 mmol/L. This was an excellent and satisfying achievement among people who have been made to feel guilty about eating sugar all their lives.