Current issues in the dietary management of children and young people with type 1 diabetes using intensive insulin therapy

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Article points

1. Nutrition management is one of the most fundamental elements of care and education for children and young people with type 1 diabetes.
2. Regular supportive contact from dietitians is required to increase dietary knowledge and adherence.
3. The authors conclude that randomised controlled trials of methods to manage postprandial glycaemia after meals high in fat and protein are needed, as well as evaluation of their acceptability to the families of those with diabetes.

Key words

- Carbohydrate counting
- Dietary management
- Intensive insulin therapy
- Protein and fat
- Type 1 diabetes

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Nutritional management is an important aspect of care for children and young people with type 1 diabetes using intensive insulin therapy. Research suggests that medical nutrition therapy should focus on interventions to ensure normal growth and development, promote lifelong healthy eating habits and maintain glycaemic control, as well as assisting with prevention of the complications associated with diabetes. In this article, the authors review the current evidence and issues regarding dietary management in children with type 1 diabetes using multiple daily injections and insulin pump therapy, and the future work needed.

The importance of glycaemic control in preventing the development of complications in type 1 diabetes was demonstrated in the Diabetes Control and Complications Trial (DCCT Group, 1993). A key component of diabetes care is effective nutritional management (Delahanty and Halford, 1993).

Whilst optimising glycaemic control is an important objective of medical nutrition therapy, a major goal in children is to establish lifelong healthy eating habits to ensure optimal nutrition for growth and development and to prevent diabetes complications (Smart et al, 2009a). It is vital that healthy eating principles, based on recommendations for all children and young people, targeting increased consumption of fruit and vegetables and decreased saturated fat intake, underlie all education (Rovner and Nansel, 2009).

Since the late 1990s, intensive insulin regimens have been utilised in paediatric centres worldwide. However, gaps remain in the evidence regarding the dietary management of childhood diabetes using intensive insulin therapy (IIT).

Carbohydrate amount and type

The International Society for Paediatric and Adolescent Diabetes (ISPAD) Clinical Practice Consensus Guidelines recommend that carbohydrate should account for 50–55% of total daily energy intake (Smart et al, 2009a). Carbohydrate intake should not be restricted as it is essential for growth. A key aspect of nutrition therapy is monitoring carbohydrate distribution, amount and type in order to balance carbohydrate intake and insulin action (Sheard et al, 2004; Wheeler and Pi-Sunyer, 2008). In regard to IIT, adjusting prandial insulin doses to match carbohydrate consumption results in more flexible dietary intakes, whereas consistency in day-to-day carbohydrate intake remains important for those on conventional therapy (Wolever et al, 1999). See *Table 1* for recommendations on carbohydrate intake for different insulin regimens.

Carbohydrate amount

The carbohydrate content of a meal is the main factor resulting in a rise in postprandial blood glucose level (Sheard et al, 2004). Increasing carbohydrate content has been shown to linearly increase postprandial

glucose (Halfon et al, 1989). Another study showed that in adults with well-controlled type 1 diabetes using multiple daily injections (MDI), changing the amount of carbohydrate in the diet did not affect glycaemic control, provided that the level of insulin was appropriately adjusted (Rabasa-Lhoret et al, 1999).

For children and young people using MDI, programmes have been developed to utilise carbohydrate counting and insulin:carbohydrate ratios (Waller et al, 2008; Anderson, 2009). In adults, data from the Dose Adjustment for Normal Eating (DAFNE) study showed that using insulin:carbohydrate ratios as an integral component of the intensive self-management programme was associated with improved glycaemic outcomes (DAFNE Study Group, 2002). Insulin:carbohydrate ratios are an important tool in IIT to optimise prandial insulin dosing and allow greater meal flexibility. However, further randomised studies are needed to support the findings of improvements in the glycaemic control and quality of life in children.

Despite universal acceptance of the importance of managing carbohydrate intake in type 1 diabetes, the best method of carbohydrate quantification has been debated. There are three methods available for quantifying the carbohydrate content of meals: estimation in exchanges (typically 15 g); estimation in portions (10 g); and "precise" carbohydrate counting to grams. Those that advocate carbohydrate counting to grams believe that this method increases the accuracy of carbohydrate estimations, allowing more exact calculations of the prandial insulin dose (Walsh and Roberts, 2006). However, research has shown that counting carbohydrates in 1 g increments does not achieve greater accuracy in carbohydrate estimations than quantifying in 10 g portions or 15 g exchanges (Smart et al, 2010).

A study comparing children, young people and their care-givers, who used one of the three different methods of carbohydrate quantification demonstrated that the accuracy in carbohydrate estimations was similar between all groups and that 73% of estimates were within a 15 g error margin, irrespective of which method of carbohydrate counting was used (Smart et al, 2010). Furthermore, as meal size increased, the accuracy of carbohydrate estimation decreased, with a trend towards greater inaccuracies in those counting in gram increments. Additionally, the study found that children who had been counting carbohydrate for a longer period of time were less accurate, highlighting the importance of providing regular carbohydrate counting updates as children grow and meal sizes change. Interestingly, in another study of young people with type 1 diabetes who were counting carbohydrate in grams, Bishop and colleagues reported that only 23% of participants were

Table 1. Recommendations for carbohydrate intake for different insulin regimens.

Insulin regimen	Meal structure and nutrition considerations
Twice-daily fixed insulin doses	Day-to-day consistency in carbohydrate intake to balance insulin action profiles and to prevent hypoglycaemia. This is usually achieved by advice to include three meals and three snacks per day containing approximately the same amount of carbohydrate on a daily basis at each meal and snack. A consistent intake of carbohydrate is usually encouraged using serves or exchange lists of measured food quantities. Prescription of carbohydrate requires regular dietetic review to ensure total energy needs are met in the growing child.
Flexible multiple daily injections (≥ 4 injections/day) using rapid-acting insulin pre-meals and long-acting insulin as basal dose	Advice to match the meal-time insulin dose to carbohydrate intake by the use of an individualised insulin:carbohydrate ratio should be considered. This allows greater flexibility in meal timing and carbohydrate intake. An additional injection may be required for snacks consisting of larger amounts of carbohydrate. However, advice regarding the quantity of carbohydrate that requires additional insulin at a snack time varies. Comprehensive education regarding carbohydrate counting is required for insulin dose adjustment.
Insulin pump therapy using a continuous subcutaneous infusion of basal insulin, with bolus doses given to match the carbohydrate quantity eaten	An individualised insulin:carbohydrate ratio should be used to enable the insulin dose to be matched to carbohydrate intake at all meals and snacks. Matching insulin to carbohydrate requires comprehensive education in carbohydrate counting. The bolus type can be adjusted to match meal composition. Missed meal boluses are an important contributor to poor glycaemic outcome.

Note: Individualised advice regarding carbohydrate amount and distribution should consider the usual appetite, food-intake patterns, exercise and energy requirements of the child or young person with diabetes.

Page points

1. A variation of up to 45% has been observed between the carbohydrate content reported on the food label and the actual carbohydrate content of the product.
2. Though the importance of the glycaemic index in the management of type 1 diabetes in children has been a subject of much debate, studies have suggested a benefit for low glycaemic index diets.
3. Further evidence is needed to justify the calculation of the fat and protein content of meals, and to ascertain whether families are able to implement them in daily life.

able to estimate daily carbohydrate within 10 g of the true amount (Bishop et al, 2009).

This raises the question of how accurate people with diabetes and families need to be in estimating meal carbohydrate content. In children with type 1 diabetes, a 10 g inaccuracy in the estimation of the meal carbohydrate content was not found to affect postprandial glycaemia, whereas a 20 g overestimate resulted in 31% of children experiencing hypoglycaemia 2–3 hours after the meal (Smart et al, 2009b; 2012). Therefore, in order to accurately count carbohydrate intake to maintain glycaemic control, carbohydrate estimations should be within 10 g of the meal carbohydrate content.

It is commonly believed that the nutrition information panel on food labels facilitates accuracy in carbohydrate counting in gram increments. However, a variation of up to 45% between the carbohydrate content reported on the label and the actual carbohydrate content of the product has been shown (Smart et al, 2011), in accordance with one set of national food standards (Food Standards Australia New Zealand, 2012). This questions the feasibility of instructing families to count carbohydrate by 1 g increments when food labels are not as accurate. Furthermore, an emphasis on carbohydrate amount, without consideration of dietary quality, may lead to increased consumption of packaged food and unhealthy eating practices (Mehta et al, 2009).

In summary, these studies suggest that the focus of carbohydrate counting interventions should not be an attempt to assist individuals to count accurately to the last gram, but rather ensuring accuracy in estimations of unlabelled foods, whilst promoting variety in healthy food choices.

Glycaemic index (GI)

The GI was defined in 1981 by Jenkins et al and ranks carbohydrate-containing foods based on their ability to raise blood glucose levels for a standardised amount of carbohydrate (Jenkins et al, 1981). The GI values of many foods have now been published (Brand-Miller et al, 2009). Whilst the importance of GI in the management of type 1 diabetes in children has been a subject of much debate, studies have suggested a benefit for low-GI diets (Gilbertson et al, 2001; Nansel et al, 2008). Ryan and colleagues demonstrated that, in children using MDI, when a low-GI meal was eaten rather than a high-GI meal, the postprandial blood glucose excursion was significantly lower at 30–180 minutes (Ryan et al, 2008). However, it is important that GI is not taught in isolation as monitoring carbohydrate amount is a key strategy in intensive therapy (Sheard et al, 2004).

Protein and fat

Protein and fat influence postprandial glycaemia in people with type 1 diabetes (Peters and Davidson, 1993; Lodefalk et al, 2008). The addition of large amounts of protein (>50 g) to meals consumed by adults with type 1 diabetes increased postprandial glucose levels at 150–300 minutes (Peters and Davidson, 1993).

Fat results in a delay in gastric emptying and, as a consequence, delays the peak glucose response and reduces the postprandial glucose excursion in children using IIT (Lodefalk et al, 2008).

In pump therapy, the meal-time insulin dose is typically calculated based on the carbohydrate content of the meal. More recently, studies have also advocated the calculation of fat and protein units in order to cover the postprandial excursions attributed to high-fat and -protein meals (Pankowska et al, 2009; 2012). However a recent clinical study using this algorithm reported hypoglycaemia in 35% of children (Kordonouri et al, 2012). The question still remains as to whether there is sufficient evidence to justify calculating fat and protein units, and whether families are able to implement it. Further studies are needed to provide evidence-based recommendations to optimise postprandial glycaemia when meals higher in fat and protein content are consumed.

Insulin bolusing for meals

For people using an MDI regimen, studies suggest that the delivery of insulin prior to meals results in improved postprandial glycaemia (Strachan and Fryer, 1998; Jovanovic et al, 2004; Ryan et al, 2008). Ryan and colleagues reported that, for low-GI meals, the administration of preprandial insulin resulted in significantly lower postprandial glucose excursions, without leading to an increase in hypoglycaemia (Ryan et al, 2008). Evidence also points to a benefit of preprandial bolus administration in pump therapy (Cobry et al, 2010; Scaramuzza et al, 2010; De Palma et al, 2011). Recent studies suggest that to diminish postprandial excursions, optimal timing of the meal bolus may be 20 minutes prior, rather

than immediately before, the meal (Cobry, 2010; De Palma et al, 2011). Further studies are needed to determine how this recommendation can be efficaciously implemented in daily clinical practice with children.

Missed meal boluses have been identified as a major cause of suboptimal glycaemic control in young people using insulin pumps (Burdick et al, 2004). Postprandial bolusing, denial of diabetes or fear of postprandial hypoglycaemia have been identified as possible contributors to missed mealtime boluses (Olinder et al, 2011). Therefore, it is advisable to recommend that boluses are given before the meal. Care-givers should be reassured that children are not at risk of hypoglycaemia if they refuse to eat immediately after insulin delivery. Furthermore, if the child eats less carbohydrate than the amount the insulin dose was calculated for, the care-giver can be reassured that he or she has time to give the extra carbohydrate, as hypoglycaemia for over-estimations in meal carbohydrate quantity is unlikely to occur until 2–3 hours after the meal (Smart et al, 2012).

An advantage of insulin pump therapy is the ability to tailor prandial insulin delivery to meal composition. In clinical practice, alterations to the insulin bolus distribution are often recommended for meals high in fat and protein (Chase et al, 2002; Jones et al, 2005). Studies of pizza meals, known to cause prolonged hyperglycaemia, have had conflicting results. Jones and colleagues found that a dual-wave bolus resulted in significantly lower blood glucose levels in the late postprandial period without causing hypoglycaemia (Jones et al, 2005). Conversely, De Palma et al found that, using a lower-fat pizza meal, the 6-hour blood glucose area under the curve was lower following a standard bolus delivered 15 minutes preprandially than the dual-wave bolus (De Palma et al, 2011)

The dual-wave bolus has also been shown to provide effective control of blood glucose levels for up to 6 hours following meals high in carbohydrate and fat (Chase et al, 2002; Lee et al, 2004). Furthermore, a dual-wave bolus prior to a low-GI meal significantly reduced the postprandial glucose excursion (O'Connell et al, 2008).

In summary, whilst there is increasing evidence that meal composition is an important factor in determining the most effective means of insulin dosing, there is yet to be consensus on the management of meals of varying macronutrient content. The extended bolus is a beneficial option for insulin distribution in children using pump therapy with multiple studies finding positive effects. However, the calculation of the optimal insulin dose for different meal types remains to be elucidated, as current algorithms may increase the risk of postprandial hypoglycaemia.

Dietary behaviours

The key dietary behaviours that have been associated with improved glycaemic outcomes are adherence to an individualised meal plan, particularly carbohydrate intake recommendations (Delahanty and Halford, 1993; Patton et al, 2007; Mehta et al, 2008); avoidance of frequent snacking episodes or large snacks without adequate insulin coverage (Delahanty and Halford, 1993; Øverby et al, 2007); regular meals and avoidance of skipping meals, particularly breakfast (Øverby et al, 2007); and avoidance of over-treatment of hypoglycaemia (Delahanty and Halford, 1993).

Medical nutrition therapy should be provided upon diagnosis and at regular intervals thereafter, to meet changes in appetite, insulin regimens and activity. Nutrition therapy should be directed towards the whole family, with opportunities such as family meals used to reinforce healthy eating and carbohydrate-counting education. Education should be individualised and part of a self-management programme that is age-appropriate, so that as children grow and are exposed to new situations regarding food, advice is tailored and targeted.

In conclusion, nutrition management is one of the most fundamental elements of care and education for children with type 1 diabetes. Regular supportive contacts from dietetic health professionals are required to increase dietary knowledge and adherence. Randomised controlled trials of methods to manage postprandial glycaemia after meals high in fat and protein are needed, as well as evaluation of their acceptability to the families of the children and young people with diabetes. ■

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Page points

1. The key dietary behaviours associated with improved glycaemic outcomes include: adherence to an individualised meal plan; avoidance of frequent snacking episodes or large snacks without adequate insulin coverage; regular meals and avoidance of skipping meals; and avoidance of over-treatment of hypoglycaemia.
2. Medical nutrition therapy should be provided for children and young people with diabetes upon diagnosis and at regular intervals thereafter.
3. Randomised controlled trials of methods to manage postprandial glycaemia after high-fat and high-protein meals are needed.

"Nutrition therapy should be directed towards the whole family, with opportunities such as family meals used to reinforce healthy eating and carbohydrate-counting education."

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