Position Statement:
Low Carbohydrate Diets for Children and Young People with Type 1 Diabetes

Summary/Recommendations

- There is limited evidence regarding the use of low carbohydrate (LCD) or very low carbohydrate diets (VLCD) in the treatment of children and young people with type 1 diabetes.
- The current available evidence has methodological limitations and meets only level 4 evidence on the Evidence-Based Medicine Scale (1)
- The available evidence suggests that LCD & VLCD are often associated with suboptimal nutrient intakes, growth disorders, unfavourable lipid profiles and potential for negative effects on bone health for children and young people with type 1 diabetes
- If a family chooses to pursue LCD or VLCD, enhanced monitoring of physical, biochemical, nutritional and psychological parameters are recommended as detailed in this statement. Any concerns arising from this monitoring should be discussed openly with the family and action plans made to address the concerns and reduce the risk of adverse complications
- Discussions with parents and families should be open and aim to foster a positive, collaborative relationship between the family and team. Consistent messaging from all team members is important
- Individual assessment with a dietitian should always be offered and encouraged to monitor and advise on nutritional adequacy on the modified diet
- Diabetic Ketoacidosis (DKA) may be more difficult to identify in those following LCD or VLCD. There should be a low threshold for medical review if the child is unwell or blood glucose levels are running higher than normal without explanation
- The use of continuous glucose monitoring (CGM) should be considered in line with local guidelines or policies
- Case studies suggest that a diagnosis of type 1 diabetes should not necessarily exclude children with intractable epilepsy from being considered for a therapeutic ketogenic diet. If recommended by the neurological team, input is required from both the neurological and diabetes teams

Introduction

In recent years, Paediatric Diabetes Dietitians are experiencing more enquiries about low carbohydrate diets from patients and their families. Increasingly, parents and young people are choosing to reject internationally recognised dietary recommendations for type 1 diabetes (2) in favour of LCD or VLCD as a management option. In response to this increased popularity, the Paediatric Diabetes Specialist Group has developed this position statement.

The aim of this position statement is to establish the British Dietetic Association's current, evidence-based recommendations regarding the use of low carbohydrate diets for young people with type 1 diabetes. This statement is intended to help inform the practice of healthcare professionals working in paediatric diabetes who are supporting families either interested in, or pursuing this management option.

What is a low carbohydrate diet?

Currently there is no internationally agreed definition of a low carbohydrate diet. The level of carbohydrate intake is often defined as the percentage energy contribution that carbohydrate makes to daily energy intake. Several definitions of low carbohydrate diet currently used in adult data are summarised in Table 1.

Table 1. Currently used definitions of carbohydrate intake (3)

Definition	Carbohydrate per day (g)	Carbohydrate % of daily energy intake*
Very low carbohydrate	20-50g	6-10%
Low carbohydrate	<130g	<26%
Moderate carbohydrate	130-230g	26-45%
* Based on an adult's 2000kcal/d diet		

These levels differ in children and young people, whose energy requirements change as they grow. Seckhold et al (4) proposed how these definitions could be applied to children's mean estimated energy requirements, summarised in Table 2.

Table 2. Suggested classification of diets according to average carbohydrate intake for children (4)

Definition	Amount of Carbohydrate (g/day)		
	Age 1-5 years	**Age 6-10 years**	**Age 11-16 years**
Very low carbohydrate (ketogenic) (<10% of total energy)	<30g	<40g	<60g

Low (<26% of total energy)	<80g	<110g	<150g
Average (~45% of total energy)	140g	200g	280g
High (>55% of total energy)	>170g	>230g	>320g

Although these figures provide a rough guide, the actual amounts of carbohydrate for an individual will differ based on age, sex, size and activity levels. Specific requirements for each patient should be calculated by their healthcare professional on an individualised basis.

Summary of Literature Review

A literature review yielded a limited number of studies relating to the use of LCD or VLCD in the treatment of children and young people with type 1 diabetes. These are summarised in Table 4, Appendix 1.

In total 11 studies were identified as relevant, 4 of which were case reviews relating to the therapeutic treatment of epilepsy or seizure disorders.

The 7 studies that related to children and young people with only type 1 diabetes were:

- 1 small prospective study (5)
- 2 case series (6,7)
- 1 survey (8)
- 3 case reviews (9,10,11)

For 3 of these studies only the conference abstracts were available, providing limited information (5,7, 9). All studies are summarised in Appendix 1.

All published studies relating to LCD or VLCD in the treatment of children with type 1 diabetes were either single case reviews or case series reporting on small numbers, with the exception of the larger survey by Lennerz et al (8). The methodologies within these included studies have inherent limitations. Consequently, the findings should be interpreted with caution. All available studies only met level 4 on the Oxford Centre for Evidence-Based Medicine Scale (1).

Type 1 diabetes and epilepsy

A clinical Ketogenic Diet used in epilepsy treatment is a high fat, low carbohydrate and moderate protein diet. There is a robust evidence base for the use of a ketogenic diet in epilepsy, Glucose transporter 1 (GLUT-1) and pyruvate dehydrogenase deficiency (12). A very low carbohydrate diet for diabetes is different to a clinically designed ketogenic diet for epilepsy. There is no restriction on protein intake, which usually is at a high level, to counteract the lack of carbohydrate foods.

An additional important difference between the two services is the variation in dietetic time available. Paediatric ketogenic diet services within the UK generally have approximately 1 whole time equivalent (WTE) per 30-35 children and young people, though the numbers are increasing (13). This is compared to paediatric diabetes with previously suggested staffing of 0.5 WTE per 100 children and young people (14).

Discussion

The current evidence available regarding the efficacy and safety of LCD and VLCD in the management of type 1 diabetes in children and young people with diabetes remains extremely limited and of low quality.

Results from the studies identified were varied, potentially due to the differing dietary intakes in the cases included. In many cases this was not possible to determine due to the limited information about actual dietary intake included in the studies.

Glycaemic Control

Some, but not all studies found improvements in glycaemic control (HbA1c, average sensor glucose and/or variability) in children when following LCD or VLCD. There was conflicting evidence regarding the risk of hypoglycaemia. One study reported increased hypoglycaemia on LCD and VLCD (6) however, the survey by Lennerz et al (8) reported decreased incidence of hypoglycaemia after commencing VLCD. Additionally, use of glucagon in the treatment of hypoglycaemia may be impaired (16).

None of the studies identified in this review reported occurrences of diabetes ketoacidosis (DKA) on LCD or VLCD, even where presence of ketones was confirmed. It should however be noted that DKA may be more difficult to recognise given the higher levels of ketones often present in those following LCD or VLCD.

Several of the included studies showed improved markers of glycaemic control which is associated with lower long-complication risk, although potential negative consequences of LCD and VLCD to growth, development, nutritional adequacy and lipids were also found.

Families who choose to follow a LCD or VLCD for their child with type 1 diabetes use HbA1c, time in range (TIR) and low glucose variability as outcome measures. HbA1c is often at a value well below 48mmol/mol. However, a large Swedish population based study (17) has suggested no additional benefit to an HbA1c below 48mmol/mol with regards to risk of nephropathy or retinopathy, and finds an increased risk of severe hypoglycaemia below this level.

HbA1c levels at or below target of 48mmol/mol can be achieved whilst eating recommended levels of carbohydrate by adopting the strategies below (18,19, 20):

- A regular structured meal pattern without significant grazing
- Appropriate daily carbohydrate quantities for age, size and activity level
- Consistent pre-prandial (15-20 minutes before food) insulin administration for meals and snacks
- Accurate carbohydrate counting and optimisation of insulin to carbohydrate ratio (ICR)
- Inclusion of good quality low GI carbohydrates
- Use of alternative bolus strategies for challenging meals (i.e. consideration of fat and protein)
- Use of continuous or flash glucose monitoring systems
- Regular data upload and analysis between clinic appointments for necessary adjustments
- Adopting an active lifestyle to improve insulin sensitivity

Growth and Development

Decreasing weight and height Z scores was evidenced in many of the included studies when following LCD or VLCD (15). In some cases where carbohydrate intake was relaxed, growth and weight measurements subsequently improved. In those cases that included nutritional analysis of the diet, energy intake was often below the estimated requirement.

Bone age was delayed by two years in one case and in another case low levels of IGF1 and growth hormone were found whilst following VLCD. One case also experienced disordered eating and amenorrhoea following her weight loss on VLCD.

There are concerns over bone health for young people with type 1 diabetes following VLCD due to reduced bone mineral density; both in those with type 1 diabetes and those on ketogenic diets (15).

Cardiovascular health

Half of the included studies that included some measure of lipids found indications of less favourable lipid profiles when following LCD or VLCD. This is concerning given the important role cholesterol plays in the development of atherosclerosis, particularly in view of the risks of cumulative exposure to atherogenic lipoproteins (21). Poor glycaemic control is associated with a potentially more atherogenic lipid profile (22).

LCD and VLCD obtain proportionally more of their energy from fat and commonly saturated fat (6, 23). This, in addition to the potential for LCD and VLCD to be deficient in micronutrients (6, 23) indicates a need for regular monitoring of lipid profiles for those following LCD or VLCD, and for careful dietary assessment and manipulation by a dietitian to ensure nutritional adequacy of the diet and the prevention of excessive intakes of saturated fat.

Eating Disorders

The incidence of eating disorders is already higher in those with type 1 diabetes compared to the general population (24). Dietary restriction is also recognised as a risk factor in the development and maintenance of eating disorders. It is recommended that monitoring for the indicators of disordered eating behaviour is undertaken in addition to physical and dietary assessment. This could be through routine psychological assessment or use of a validated screening tool (25).

Insulin

Many following LCD or VLCD follow Dr Bernstein recommendations (26). This approach may lead to patients following LCD or VLCD and using multiple daily injections (MDI) to request short acting insulin for meal doses, in preference to rapid acting analogue insulin. In the UK this is available as Humulin S (Eli Lilly and Company Ltd), Actrapid (Novo Nordisk Ltd) and Insuman Rapid (Sanofi). The slower absorption profile of these insulins better fits the delayed rise in glucose from gluconeogenesis from protein, allowing more generous doses to be administered.

In this approach, rapid acting insulin is the preferred option for correction doses which may be given intramuscularly (IM). Basal insulin is always split, bd or tds depending on the product, and often differing from manufacturer's recommendations for frequency.

Patients following LCD or VLCD using insulin pump therapy can use rapid acting analogue insulin, making necessary adjustments via the pump functionality.

These departures from usual practice would need to be discussed with the local diabetes team.

Type 1 diabetes and epilepsy

Published individual case reports (27, 28, 29) would suggest that a therapeutic ketogenic diet is safe for children with type1 diabetes and epilepsy, with appropriate support from neurological and diabetes teams. However, secondary to risk of impaired growth, renal stones, brittle bones, vitamin deficiency, increased blood lipid levels and possible impact of menstruation or bruising, the ketogenic diet for treatment of paediatric epilepsy is not continued longer than 2 years as standard. The majority of UK paediatric neurology teams who use a therapeutic ketogenic diet recommend a trial on a standard diet after 2 years due to the above (12).

One important difference when comparing ketogenic diets in epilepsy and low carbohydrate diet in diabetes is ketone levels when unwell. In ketogenic diets for epilepsy ketone levels are often seen to decrease when unwell, the opposite would be expected to be seen in paediatric diabetes.

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Suggested Monitoring

A clinical protocol, created by an interdisciplinary team reviewing similar evidence as this statement, has been suggested for patients following LCD or VLCD (15). This aims to ensure the health and wellbeing of children and young people by evaluating their progress and enhanced monitoring.

Screening tests in addition to the routine annual review checks are recommended to identify and areas of concern for children and young people following LCD or VLCD. This has cost implications both for the NHS and for individuals in countries with different health funding models. These are summarised in Table 3.

Table 3. Monitoring recommendations for children and young people following LCD or VLCD – adapted from Kossoff et al (12) and Seckhold et al (4).

Nutritional evaluation by a registered dietitian at baseline, after 3 months then minimum annually while on LCD or VLCD	• Weight and Ideal weight for stature • Height and Height velocity • BMI
	• Review appropriateness of meal plan (calories, protein, fibre and fluid)
	• Review need for vitamin and mineral supplement
	• Assess adherence to diet in all settings inside and outside the home
Medical evaluation by diabetes specialist team at baseline then 3 monthly	• Glycaemia and insulin dosing
	• Level of ketosis (blood ketones) to establish baseline level of ketosis and frequency thereafter to be agreed by local diabetes team
	• Efficacy of the diet – is it meeting parental expectations?
Laboratory assessment at baseline, after 3 months and annually while on LCD or VLCD	• Complete blood count with platelets
	• Electrolytes to include serum bicarbonate, total protein, calcium, magnesium and phosphate
	• Serum liver and kidney profile (including albumin, AST, ALT, blood urea, nitrogen and creatinine)
	• Vitamin D level
	• Fasting lipid profile to include total cholesterol, HDL cholesterol, LDL cholesterol and non-HDL cholesterol
	• Urine analysis
	• Urine calcium and creatinine
Additional	• Bone mineral density (DEXA scan) at baseline then after 2 years of following LCD or VLCD
	• Renal ultrasound at baseline and annually while following LCD or VLCD
	• If DKA is suspected during times of sickness or high blood glucose levels there should be a low threshold for medical review including measurement of pH and bicarb
	• Screening for disordered eating behaviours at baseline and annually through routine psychological assessment or using a validated screening tool (24)

Appendix 1 - Literature Review

Low Carbohydrate Diets for Children with Type 1 Diabetes

Glycaemic Control

All studies identified in the literature review included at least some measurements of glycaemic control. There were mixed results from the studies. 4 out of the 7 studies reported improvements to glycaemic control on either LCD or VLCD (5, 8,10,11).

Arslanoglu (5) found that mean sensor glucose and Area Under Curve (AUC) were significantly lower after 3 days on VLCD (P<0.013, 0.022 respectively) compared to 3 days on standard carbohydrate diet, with blood ketones higher on VLCD. However this study was limited by its extremely short duration, therefore it is not possible to identify whether improvements in mean sensor glucose or AUC are sustained. Very little detail regarding the study was available as it was a conference abstract only. It also focused on adolescents with poor glycaemic control which raises questions over the potential for missed bolus insulin, inaccurate reporting of diet and inaccuracy of carbohydrate being bolused for. It was further limited by its failure to provide any detail regarding dietary intake, other than carbohydrate amount, on either diet.

Similarly, the large (n=316) international survey by Lennerz et al (8) found that mean sensor data was low (within target ranges) during VLCD (5.8mmol/l ± 0.89) with low variability. This survey also found a significant mean reduction in HbA1c of 1.45mmol/l ±1.04% (P<0.001) with an average HbA1c of 5.71%±0.58% in the 131 paediatric participants following VLCD. Hypoglycaemic events were reported as low and reduced in number in comparison to before the commencement of VLCD. It is worth noting however that hypoglycaemia level was not defined. On VLCD, diabetes-related hospitalisations also significantly decreased (p<0.001) as did emergency encounters relating to hypoglycaemia (p=0.001). There were no hospitalisations due to DKA in the paediatric group. Although these results suggest beneficial effects of VLCD on glycaemic control, selection bias was evident as the participants volunteered to complete the survey were a self-selected sub-set of an online group that were advocates of, and followed a VLCD for diabetes treatment. The sample was generally highly educated and of higher socio-economic status. Furthermore, the survey only included those that had followed the diet for >3 months, which, although useful in providing more than just immediate-term data, likely excludes those for which the VLCD approach was not successful and/or sustainable. These factors limit the generalisability of these findings to the wider type 1 diabetes population. Several of the authors of the study are also well-known advocates of VLCD and gain financially from selling services or information about this approach. Indeed, the survey respondents were following the suggested dietary approach in one of the author's books (26). These conflicts of interests were clearly stated in the article.

Both case reviews by de Souza Bosco Paiva & Lima (11), and McClean et al (10) also suggested improvements in glycaemic control measured by HbA1c on VLCD. HbA1c on VLCD was 4.8% within three months of diagnosis in the case described by de Souza Bosco Paiva & Lima (11) and 5.9% on VLCD in McClean et al case (10). Additionally, de Souza Bosco Paiva & Lima (11) found average blood glucose levels were lower and with reduced variability on VLCD (7.6mmol/l vs 4.8mmol/l and range of 3.6-18.5mmol/l vs 3.1-10.4mmol/l). Notably though, the case described by de Souza Bosco Paiva & Lima (11) had only just been diagnosed when they chose to start VLCD.

Conversely, the case series described by de Bock et al (6) and Ford-Adams et al (7) showed variable effects of LCD and VLCD on glycaemic control. In de Bock et al (6), only 1 of the 6 cases clearly reported a reduction in HbA1c (6.1% to 4.9%) however sensor data in this case suggested significant hypoglycaemia (<3.9mmol/l 20% of time). HbA1c in 4 out of the 5 other cases ranged between 6.4 and 10.4% on LCD or VLCD with no comparison data whilst not restricting carbohydrate. Thus, it was not possible to ascertain if there was a reduction in HbA1c. The remaining case did not report HbA1c whilst following VLCD.

5 out of 6 of the cases that Ford-Adams et al (7) described experienced reductions in HbA1c on LCD or VLCD. One of these cases was only negligibly lower on LCD compared to 45% EAR from carbohydrate (48-51mmol/mol vs 53mmol/mol, 6-6.8% vs 7%). However one case showed an increase in HbA1c from 38 to 54mmol/mol (5.6-7.1%) initially which coincided with coming out of honeymoon phase. After 20 months on LCD HbA1c 45mmol/mol (6.3%).

The case review by Klee et al (9) did not have results to compare pre and post-VLCD as the diet was implemented prior to diagnosis of type 1 diabetes. This case did achieve good glycaemic control on VLCD (HbA1c range 5.9-7.3%). Ketones remained within normal ranges and hypoglycaemia was described as “rare”.

Growth & Development

Some studies reported on growth and development (6, 7). Both case-series (6, 8,9,10) highlighted negative effects of LCD and VLCD’s on growth of children and young people with type 1 diabetes. In the case series by de Bock et al (6) all 6 cases experienced reductions in weight whilst on LCD or VLCD. Meanwhile, 2 of the cases that reported on height, also showed reductions in height following LCD or VLCD. Similarly, in the Ford-Adams et al case series (7), weight z-score dropped in 5 out of 6 cases and height z-score dropped in 3 out of the 4 cases that reported on height. Both weight and height z-score increased in 1 of the 6 cases. It is also worth noting however that 1 of the cases was significantly overweight to begin with, and was following a LCD in an attempt to lose weight.

In one of the cases described by de Bock et al (6) bone age was delayed by 2 years and in another case low levels of IGF1 and growth hormone were found whilst

following VLCD. One of the cases a 12 year old female following a VLCD also experienced disordered eating and amenorrhoea following her weight loss on VLCD.

Although valuable in contributing to an area where there is a dearth of literature, both case-series (6, 7) are limited by their methodologies and the small numbers of cases described. Due to the small numbers involved, these cases may not be representative of all young people with type 1 diabetes that follow the LCD or VLCD approach. Several of the cases do provide follow up data over a period of more than 1 year, however only 1 case in de Bock et al (6) reported outcomes over a period of more than 5 years. Additionally, as only the abstract was available for Ford-Adams et al (7) very limited detail could be determined.

The findings of the 2 case series (5,6) were supported by the findings of the survey by Lennerz et al (8) who found the provider reported height z score dropped (P=0.05) on VLCD from 0.41±1.02 at diagnosis (pre-diet) to 0.20±1.27 in the small sub-set of children for which this data were available (n=3 26%). However, no correlation was found between height score and carbohydrate intake goal or diet duration.

On the contrary, the case studies by Klee et al (8) and McClean et al (10) did not show any negative effects of VLCD on growth. Klee et al(9) described weight and linear growth as "normal" after two years on VLCD in a child that commenced VLCD at 7 years of age, prior to diagnosis of type 1 diabetes and continued on the diet post-diagnosis. Similarly, McClean et al (10) described the case of a 5 year old who followed a VLCD for more than 4 years, whose weight and height were stable on the 75th centile. Both these studies indicated considerable time spent preparing suitable, home-made meals and snacks and in both cases the whole family adopted the VLCD, although in McClean et al (10) 1 of the siblings and the mother discontinued the VLCD after 3 months due to finding it too restrictive and feeling low in energy.

Dietary Adequacy

Only 1 study reported on dietary quality (6). Energy intake was found to be below estimated requirements in the 3 studies that reported on it. In all of the cases where nutritional assessment was undertaken, calcium intake was found to be below recommended daily intake (RDI). Additionally, thiamine, phosphorus and magnesium intake were found to be lower than RDI in some of the cases and 1 of the cases found that sodium intake was 406% of the recommended limit.

Cardiovascular Health

Four studies reported on markers of cardiovascular health (6, 8,10).

Both the case series by de Bock et al (6) and the survey by Lennerz et al (8) found increased levels of total and low-density lipoprotein (LDL) cholesterol in young people with type 1 diabetes following LCD or VLCD. In all the cases where total cholesterol was reported in de Bock et al (6) it was raised and in the 1 case that

reported LDL cholesterol and triglycerides it was raised. Similarly, average total cholesterol 198±52mg/dl (5.12±1.34mmol/l) was raised in the paediatric participants of the Lennerz et al survey (8). Average LDL cholesterol was also raised with an overall mean of 147±83mg/dl (3.8±2.15mmol/l) among all participants and a mean of 124±26mg/dl (3.21±0.67mmol/l) among the paediatric subgroup. Dyslipidaemia was present in 62% of those that provided data and in the paediatric subgroup, 43% of children had provided data. However only ~11% of caregivers that responded to the survey provided data on lipids. This may be due to the fact that lipid screening at annual review is not recommended routinely until 11 years of age in current guidelines (30).

Contrastingly, the case studies by Klee et al (9) and McClean et al (10) both reported that lipid measurements remained within normal limits after more than two and four years on the VLCD respectively.

Ketogenic Diets for Concomitant Seizure Disorders and Type 1 Diabetes

In rare cases an individual may have both type 1 diabetes and intractable epilepsy.

There are 3 published case reports of children with both conditions (27, 28, 29). These report a successful neurological outcome with no adverse glycaemic consequences. There were no reported events of DKA post diagnosis of diabetes, despite high daily levels of ketones (>2.5mmol/l) or severe hypoglycaemia, despite carbohydrate intake of less than 30g/day. HbA1c results were within an acceptable range. Growth, where reported, showed no adverse consequences.

There was also one case report of a child diagnosed with type 1 diabetes with Pyruvate Dehydrogenase Deficiency (31). Similarly to the 3 case reports of children with type 1 diabetes and epilepsy, there were no adverse glycaemic consequences with excellent glycaemic control for the duration of follow up though hypoglycaemia was not discussed. Growth improved during the follow up period but this was likely due to diagnosis and treatment of diabetes.

Table 4: Summary of studies identified from literature review

Citation	Study Details	Outcomes	Key Results
Arslanoglu I. Is low carbohydrate diet an alternative in poorly controlled late adolescent type 1 diabetic girls? *Pediatric Diabetes.* 2012; 13, 137 (Conference abstract).	Turkish prospective study on 10 adolescent girls with poorly controlled diabetes (HbA1c 7.8-12.2%). Cross-over design of standard carbohydrate diet (152g±51) for 3 days followed by VLCD (46g±16) for 3 days.	• Glucose sensor data • Blood beta OH butyrate (βOHB), • Insulin dose	• Insulin dose decreased from 69.7±23.8 to 60.3±24.4IU on VLCD • Mean sensor glucose and Area Under Curve significantly lower on VLCD (P<0.013, 0.022 respectively) • βOHB significantly higher during VLCD (P<0.011)
De Bock M et al. Endocrine and metabolic consequences due to restrictive carbohydrate diets in children with type 1 diabetes: An illustrative case series. *Pediatric Diabetes*. 2012; 19, 129-137.	Case series of 6 cases: 1. 13 year old Male on Multiple daily injections (MDI) commenced LCD (<90g/d) then VLCD (<60g/d) Stopped VLCD after 2 years and increased CHO to 150g/day	• HbA1c • Weight SDS • Fasting total cholesterol • Dietary adequacy (calcium & thiamine)	• HbA1c 3 & 8months after diagnosis (prior to LCD/VLCD) 6.1% and 5.9%. HbA1c not reported during LCD/VLCD On 150g/CHO/d HbA1c 6.3% • Weight decreased from -1.22 to -1.88 SDS on LCD/VLCD & increased to -1.31 on 150g/CHO/day • Elevated fasting cholesterol 5.5mmol/l after 2 years of LCD/VLCD (no data from before diet) • Calcium & thiamine intake low on LCD/VLCD (<70% RDI) • VLCD ceased after 2 years due to intolerability, fatigue & hunger after cycling training
	2. 12 year old female on insulin pump therapy. Commenced VLCD in effort to lose weight. Reduced carb intake to ~50g/d initially, then 22g/d. Stopped VLCD after 2 years & increased CHO to 120-140g/d	• HbA1c • BMI SDS • Fasting total cholesterol • Blood pressure (BP) • Dietary adequacy (calcium)	• Lowest reported HbA1c during VLCD was 6% and highest 8.1%. No HbA1c data before or after VLCD. • BMI dropped from 1.31 SDS @ onset of VLCD to 1.26 during, continuing to drop further on VLCD. Experienced amenorrhoea on VLCD • Elevated fasting total cholesterol 5.7mmol/l on VLCD (no data for before/after diet) • Systolic BP 95th centile on VLCD (no data pre/post-diet) • Low vitamin D & calcium <50% RDI on VLCD • Stopped VLCD after 2 years due to disordered eating, psychological issues and poor concentration and enjoyment of sports. Menarche returned.

	3. 6 year old male on MDI. Commenced LCD 2 weeks post-diagnosis (~75g CHO/d dropping to 50-60g/day for several months	• Weight SDS • HbA1c • Fasting total cholesterol & LDL cholesterol & triglycerides • Dietary adequacy (energy & calcium)	• Weight SDS -0.22 at diagnosis dropping to -0.55 after 2 months LCD. Continued to drop on LCD. Weight SDS improved on liberalised CHO intake -0.1 SDS • HbA1c 7.9% after ~5 months on LCD (no data pre/post diet) • Elevated fasting cholesterol 6.3mmo/l, LDL cholesterol 3.04mmol/l & triglycerides 1.66mmol/l on LCD • LCD met <70% energy and 28% Calcium needs • Hunger/ food-seeking behaviour reported at school during LCD • Breakdown in relationship between parents and diabetes team
	4. 4 year old female on twice-daily insulin regime commenced LCD within 4 months post-diagnosis (<40% of energy intake) – continued on LCD for >7years until lost to follow up	• Weight & height SDS • HbA1c & hypoglycaemia • Fasting total cholesterol • Bone age • Dietary adequacy (energy, calcium, phosphorus & magnesium)	• Shortly post-diagnosis weight -1.49 SDS. Height SDS -2.0. After 7 years on LCD weight SDS -1.77 and height SDS – 3.28 • HbA1c 6.4-10.4% during follow up on LCD (Mean 8.1%) • Frequent mild & moderate hypoglycaemia. No severe hypoglycaemia or DKA. • Elevated fasting total cholesterol 5.2mmol/L on LCD • Bone age delayed by 2years • Diet met 76% of expected energy requirement, 47% of calcium, 70% of phosphorus, & 74% magnesium RDI • Breakdown of relationship between carers (grandparents) and diabetes team. Involved social services
	5. 3½ year old male on insulin pump therapy. Commenced VLCD 18 months post-diagnosis (CHO approx. 6% of energy increasing to 45g carb/day)	• HbA1c • Sensor glucose • Height & weight SDS • Fasting total cholesterol HDL & triglycerides • Dietary adequacy (energy, calcium, sodium) • Serum magnesium, vitamin B1, folate. • IGF1 & growth hormone	• HbA1c decreased from 6.1% to 5.3% on VLCD initially, later dropping to 4.9% • 20% sensor glucose values <3.9mmol/l, 3% <2.9mmol/l • Height SDS dropped from -1.36 at diagnosis to -2.36 Weight SDS dropped from +1.31 SDS to -0.86 • Fasting total cholesterol 4.7mmol/l, normal HDL & triglycerides during VLCD • VLCD met 86% of estimated energy requirements (6% from CHO, 67% from fat of which 36% from saturated fat), 406% of recommended sodium intake & 50% calcium RDI • Serum magnesium vit B1 & folate normal • IGF1 low (<25µg/l increasing to 28 µg/l), Growth hormone low (4.3mU/l)

	6. 3½ year old female on insulin pump therapy. Tried LCD at 3 ½ years of age for 1 month, then VLCD (40gCHO/day) at 6 years for 3 months.	• HbA1c • Height & Weight SDS	• HbA1c 7.3-7.8% on VLCD • Weight SDS +0.07 , -0.31 at VLCD onset and dropped to -0.89 after 3 months on VLCD • After returning to average CHO diet (140-150g/day) gained 3.7kg and returned to pre-VLCD weight centile • Ceased diet due to parental concern over daughter looking unwell and tired and waking in night hungry
Ford-Adams M et al. Retrospective case reviews of children with type 1 diabetes following low carbohydrate diets, less than 40% daily energy requirement (EAR) against the advice of the multi-disciplinary team from Young Diabetes Connections (YDC) Network, and Queen Mary's Hospital London. *Pediatric Diabetes*. 2018; 19, 26 (Conference Abstract).	Case notes review of 6 patients 1. 1 year old commenced LCD (60-109gCHO/day = 22-29% EAR)	• Weight & Height & weight& height z scores • HbA1c	• Weight increased from (0z) to 3.495z during LCD. 2years later on 45% EAR from CHO weight 16.98 kg (1.06z) • Height increased from 80.6cm (1z) to 93.4 cm (1.978z) during LCD. 2years later on 45% EAR from CHO height 101.2 cm (0.79z) • HbA1c 42-51mmol/mol (6-6.8%) on LCD, 53mmol/mol (7%) on 45% EAR from CHO
	2. 3 year old commenced VLCD 20gCHO/day =7% EAR, increasing to 40gCHO/day = 11% EAR 1 year later	• Weight & Height & weight& height z scores • HbA1c	• HbA1c dropped during VLCD from 60mmol/mol (7.6%) pre-diet to 48mmol/mol (6.5%). 1 year later on 40gCHO/day HbA1c 53mmol/mol (7%) • Weight became static at 6 months of VLCD & dropped in z score after 1 year on VLCD 0.08-0.01z. No pre-diet data • Height z score dropped from 0.26 after 6 months on VLCD to 0.0 after just over a year of VLCD
	3. 6 year old commenced LCD (60-114gCHO/day = 13-28% EAR)	• Weight & Height & weight& height z scores • HbA1c	• HbA1c increased from 38 to 54mmol/mol (5.6-7.1%). After 20months LCD HbA1c 45mmol/mol (6.3%) • Weight: After 11 months LCD weight z score increased from 0.638-0.83z. After 20months LCD this dropped to 0.598z • Height: After 11 months on LCD height increased from 1.037-1.164z. After 20 months LCD height z score 1.14z
	4. 8 year old commenced LCD 111g CHO/day (25% EAR)	• Weight & Height & weight& height z scores • HbA1c	• HbA1c dropped on LCD from 75-67mmol/mol (9-8.3%). When stopped LCD HbA1c dropped further and stabilised at 56mmol/mol (7.3%) • Growth slowed & weight became static on LCD. Height z score dropped from 1.75-1.51. On ceasing LCD height z score stabilised 1.52z

	5. 10 year old commenced LCD 81gCHO/day (26% EAR)	• Weight & Height & weight& height z scores • HbA1c	• HbA1c dropped from 79-40mmol/mol (9.4-5.3%) after 6 months LCD • Weight z score dropped from 0.93-0.61 after 6 months LCD & later dropped to 0.5 • Height z score dropped from 1.18-1.08 after 6 months LCD & later dropped to 0.9
	6. 17 year old commenced LCD 100g/day (13% EAR) in attempt to lose weight	• Weight & Height & weight& height z scores • HbA1c	• HbA1c dropped from 66-59mmol/mol (8.2-7.6%) on LCD. Stabilised on LCD after 21months • Weight increased initially from 92kg (2z) to 99kg (3z) but after 21 months LCD lost 7kg.
Lennerz BS et al. Management of Type 1 Diabetes With a Very Low-Carbohydrate Diet. *Pediatrics.* 2018; 141 (6), 1-10.	International online survey of those following VLCD (weight-based CHO prescription of <30g carb/day) for >3 months. Average CHO intake 36g day, Mean duration of diet 2.2±2.9 years 131 (42%) were parents of children with T1DM – average age of paediatric participants 9±4years , the remainder adults with T1DM. Members recruited via volunteer sample – sample was generally highly educated & higher socio-economic group	• Glycaemic control: HbA1c, mean BG, • Adverse events: hospitalisations in last 12 months, DKA, symptomatic hypos in last month, severe hypos in last year. • CVD risk: Triglycerides, HDL, LDL and total cholesterol	• Average HbA1c 5.67%, (5.71%±0.58% in paediatric participants) • Significant mean reduction in HbA1c on VLCD 1.45% • CHO intake significantly correlated to HbA1c • Low average sensor glucose & low variability in both adults & children. Overall mean 104mg/dl ± 16 (5.8mmol/l ± 0.89) with a SD of 28mg/dl± 12 (1.56mmol/l ± 0.37) • Low incidence of adverse events. Adverse events reduced in number following VLCD. Diabetes-related hospitalisations significantly decreased (p<0.001) as did emergency encounters relating to hypoglycaemia (p=0.001). There were no hospitalisations due to DKA in the paediatric group • Total cholesterol: Overall Mean 234 ± 89mg/dl (6±2.3mmol/l). In children 198±52mg/dl (5.12±1.34mmol/l) • HDL cholesterol: Overall Mean 74±21mg/dl (1.91± 0.54mmol/l). In children Mean 65±21mg/dl (1.68±0.54mmol/l) • LDL cholesterol: Overall Mean 147±83mg/dl (3.8±2.15mmol/l). In children Mean 124±26mg/dl (3.21±0.67mmol/l) • Triglycerides: Overall Mean: 74±37mg/dl (0.84±0.42mmol/l). In children Mean: 68±33mg/dl (0.77±0.37mmol/l) • Dyslipidaemia present in 62% of those that provided data. 43% of children that provided data. • Height z score dropped (P=0.05) form 0.41±1.02 at diagnosis to 0.20±1.27 in the small sub-set of children for which this data were available (n=34).
Klee et al. A low-carbohydrate diet improves metabolic control in a type 1 diabetic child without side effects. *Hormone Research in Paediatrics*. 2019; 91, 536-537 (Conference Abstract).	Case review of a child that commenced VLCD at age of 7 years, prior to diagnosis of T1DM. Case described after 2 years on VLCD. Developed T1DM aged 8 years & continued on VLCD(10-30gCHO/day). Also took daily supplements of omega 3, vitamins A, B1, B2, B6, C, D E, K, folic acid & niacin	• HbA1c • Ketones • Insulin dose • Hypoglycaemia • Cholesterol • Growth	• HbA1c ranged from 5.9-7.3% post-diagnosis • Insulin dose 0.11-0.24IU/kg/day • Ketones within normal ranges • Hypoglycaemia described as “rare” but not defined • Weight and linear growth described as normal • Lipid & cholesterol results described as normal • Almost everything eaten home-made

de Souza Bosco Paiva & Lima. Introducing a very low carbohydrate diet for a child with type 1 diabetes. *British School of Nursing*. 2019; 28 (15), 1015-1019.	Case review of a 5 year old male commenced on a VLCD (30gCHO/day, 70g protein/day, 55g fat/day) within weeks of diagnosis. Required diluted insulin. Also took Vitamin D & omega 3 supplements	• Glycaemic control (average blood glucose, time in range, HbA1c) • Insulin dose	• In the 2 weeks post-diagnosis before commencing VLCD average blood glucose was 137.3mg/dl (7.6mmol/l), Range between 65 and 330 mg/dL (3.6–18.5 mmol/L). On VLCD average blood glucose 87.5 mg/dL (4.8 mmol/L). Range stayed within 57-189 mg/dL (3.1–10.4 mmol/L) • HbA1c decreased from 10.9% 1 week post-diagnosis to 4.8% within 3 months on VLCD • Time in range on VLCD 95% • Daily insulin dropped from 5.2 to ~1.1units per day
McClean et al. Can a ketogenic diet be safely used to improve glycaemic control in a child with type 1 diabetes? *Archives of Disease in Childhood*. 2019; 104, 501-504.	Case review of 5 year old male on MDI commenced on a VLCD (<50gCHO/day) for > 4 years In addition the authors conducted a literature review	• HbA1c • Insulin dose • Growth • Lipids	• HbA1c 70mmol/mol (8.6%) at diagnosis. On VLCD 41mmol/mol (5.9%). No other data available on HbA1c • Basal insulin 0.3u/kg/day, Bolus insulin 0.25 units/kg/day on VLCD. Total insulin dose not stated at diagnosis prior to VLCD but basal was 0.2units/kg/day • Stable on ~75th centile for weight & height on VLCD. • Lipids & ECG reported as normal
Dressler A et al. Type 1 diabetes and epilepsy: efficacy and safety of the ketogenic diet. *Epilepsia*. 2010; 51 (6): 1086-1089.	Case review of a 3y female with T1 diabetes diagnosed at 18/12, commenced on VLCD ketogenic diet for epilepsy at 3y 6m for duration of 15m. Diet stopped due to refusal of ketogenic meals	• HbA1c • Growth • Hypoglycaemia • Seizure frequency • Developmental improvement	• HbA1c improved from 7.9% to 6.2% over 13m • Growth reported as normal • No severe hypoglycaemia or ketoacidosis • No deficiency in Zinc or Selenium levels • Initial improvement in seizure frequency • Gain in language and motor skills observed
Aguirre Castaneda, Mack, Lteif. Successful treatment of Type 1 diabetes and seizures with combined ketogenic diet and insulin. *Paediatrics*. 2012; 129 (2): 511-514.	Case review of a 4y female with epilepsy diagnosed at 4/12, and following a VLCD ketogenic diet for epilepsy. T1 diabetes diagnosed at 2y and resumed VLCD post DKA episode for further 10m. Follow up for duration of 22m. Diet stopped after 10m due to child's wish for other foods.	• HbA1c • Ketone measurement • Hypoglycaemia • Growth • Seizure frequency	• HbA1c maintained from 7.3% to 7.2% on ketogenic diet, increased to 8.2% after discontinuation of diet, measured at 22m post diabetes diagnosis • Moderate ketones maintained while on ketogenic diet • No severe hypoglycaemia or ketoacidosis • Wt and height centiles maintained while on ketogenic diet • Seizures controlled on diet and then successfully with medication alone
Aylward, Shah, Sellers. The ketogenic diet for the treatment of myoclonic astatic epilepsy in a child with type 1 diabetes mellitus. *Can J Diabetes. 2014;* 38 (4):223-224.	Case review of a 3y male diagnosed with T1 diabetes at 3y9m, followed by myoclonic astatic epilepsy soon after. Low GI KD started initially but unsuccessful. Condition deteriorated and started classic KD tube feed via gastrostomy at 4y11m, continued for 6y.	• HbA1c • Ketone measurement • Hypoglycaemia • Seizure frequency • Developmental improvement	• HbA1c maintained between 5.7% and 6.4% on ketogenic diet • Moderate to large ketones maintained • No severe hypoglycaemia or ketoacidosis • Significant decrease in seizure activity • Significant improvement in cognitive function
Henwood , Thornton & Preis. Reconciling Diabetes Management and the Ketogenic Diet in a Child with Pyruvate Dehydrogenase Deficiency. *Journal of Child Neurology.* 2006; 21, 436-439	Case review of 4y old diagnosed with T1 diabetes who had pyruvate dehydrogenase deficiency. The child had been treated with ketogenic diet since 2y 9m. Carbs were 5.5g per meal. 28 month follow up	• HbA1c • Ketone measurement • Developmental improvement • Seizure activity • Linear growth	• HbA1c 5.1%, 10 months post-diagnosis • No severe hypoglycaemia or ketoacidosis • Ketones maintained between 0.7-2.0mmol/l • Linear growth increased from 91.5cm (<5th centile) to 104cm (50th centile), weight stable on 50th centile

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