Irish Medical Journal
Established 1867

Issue: Ir Med J; Vol 113; No. 9; P176

Accuracy of Carbohydrate Counting in Patients with Type 1 Diabetes Using Insulin Pump Therapy

L. Keaver[1], L. Coll[1], S. Mulvaney[1], L. Kelly[2], C. McHugh[2]

1. Department of Health and Nutrition Science, Institute of Technology Sligo, Ireland.
2. Sligo University Hospital, Ireland.

Abstract

Aim

To investigate the ability of patients with Type 1 Diabetes to visually estimate the carbohydrate content in meals/snacks, and to evaluate difficulties and concerns regarding CC.

Methods

Nineteen patients with Type 1 diabetes on insulin pump therapy who presented consecutively at an outpatient clinic were asked to visually estimate the carbohydrate content in 15 meals and snacks and complete a questionnaire around their experience of CC.

Results

Over half the participants felt confident/very confident about incorporating CC into daily life, 84.2% (n=16) reported not finding CC difficult and 68.4% (n=13) found apps a helpful aid. The mean score for the carbohydrate content assessment was 4.7 (SD =2, min = 1 and max = 8). Sixteen (84.3%) found fat/calorie dense meals difficult to account for. In addition, 42.1% (n=8) avoided certain foods as they could not gauge the carbohydrate content. Five (26.3%) felt it complicated the management of their diabetes while 42.1% (n=8) felt their blood sugars fluctuated a lot even if CC.

Conclusion

Despite appropriate and comprehensive education in CC these skills decline with time and repeated interval education is important. We recommend the introduction of regular refresher courses within the healthcare setting to improve diabetes management.

Introduction

Carbohydrate counting (CC) is a practical meal planning technique which involves accurate estimation of carbohydrates in meals in order to consequently determine a bolus insulin dosage. It is therefore an important part of the medical management of those with type 1 diabetes.

Past work has highlighted the positive impacts CC has on reducing Hb_{A1C} and improving quality of life among participants[1]. However, the efficacy of CC is largely dependent on the extent of education and training received[2].

In Ireland training in CC is often provided at the onset of diabetes which may well be as early as childhood or adolescence[3]. However, these skills are rarely reviewed or updated in Ireland unlike other countries such as England and Germany where programmes are in place for the routine provision of diabetes education retraining[4,5,6]. In Germany The Düsseldorf Diabetes Treatment and Teaching Programme is 5-day programme to retrain patients to measure insulin dosages according to the meals to be ingested. Outcomes from this have shown long-term sustainability in blood glucose levels[7] and similarly in the UK the introduction of the REACCT (Re-education and Carbohydrate Counting Training) programme has improved confidence in CC for people with T1D[8]. The absence of such programmes in Ireland is a major flaw in the Irish diabetic education programme as knowledge and certainty have been known to decline overtime[9]. This could lead to the misinterpretation of carbohydrate quantities and the miscalculation of insulin dosages therefore resulting in inappropriate dosing of insulin[10].

A national review of diabetes structured education carried out in 2009 outlined as one of their seven recommendations that Diabetes structured patient education should be available to all people with diabetes at diagnosis and at regular intervals thereafter[11]. However, there is no indication as to what duration of time regular intervals reflect or how current resources can be utilised to ensure that this is possible.

Currently dietitians and diabetes nurses in Sligo University Hospital, as in other hospitals around the country, only have the resources to deal with priority patients and therefore although providing appropriate education (Berger) and support for those with type 1 diabetes at diagnosis, it is not currently feasible to provide refresher courses due to the time-consuming nature of these education activities.

It is clearly crucial for people with T1D to be able to effectively identify and quantify carbohydrates to reduce the likelihood of inappropriate dosing and ultimately adverse complications[12]. The aim of this research is to assess the accuracy of CC by visual estimation of the carbohydrate content of prepared meals and snacks, and to provide a questionnaire to evaluate difficulties and concerns among people with T1DM on CSII who have previously received a training course in CC.

Methods

This cross-sectional study recruited adults over the age of 18 who were on insulin pump therapy from the diabetic outpatient clinic in Sligo University Hospital (SUH) between October 2018 and May 2019. Those with gestational diabetes and those who were receiving insulin by means of multiple daily injections were excluded. A 16-item questionnaire based on previous research[6] was devised to assess patients views and experiences with carbohydrate counting.

A total of 15 meals and snacks were chosen and prepared based on recommendations of the Irish Nutrition and Dietician Institute (INDI) and a diabetes specialist dietitian and reflected foods which are most commonly consumed by an Irish population. Carbohydrate free meals and carbohydrate rich meals were included to adequately test the knowledge and ability of participants. Item were weighed and with the help of nutritional labels the carbohydrate content was calculated and noted. Where no nutritional label was provided (n=4) foods were weighed and carbohydrate content was calculated using carbohydrate counting reference tables where the following equation was applied to food; Weight of food (g)/100 x CHO content per 100g.

The study took place in a separate room from the outpatient clinic and participants were asked to estimate the carbohydrate content of each food item and answer the questions that followed.

Meals were presented uniformly on white plates spread evenly across a table accompanied by individual reference numbers. An estimation error of 10% above or below actual carbohydrate content was allocated.

HbA1c was obtained from the online lab system used within Sligo University Hospital. The most recent HbA1c value available at the time of taking the CHO counting test was used. Data was analysed using SPSS™ version 24 and significance was set at $p<0.05$. Ethical approval was granted by the Sligo University Hospital Research Ethics Committee and informed written consent was obtained from all participants before enrolment in the study.

Results

Participant characteristics

The majority of participants were female (n=18, 94.7%), over 40 years (n=10, 52.7%), diagnosed with diabetes for >20 years (n=14, 73.7%), using an insulin pump for ≤6 years (91.8%) and received CC training in the last 4 years (n=13, 71.2%). The mean HbA1c was 57±9.7 mmol/mol. Over half felt confident or very confident about incorporating CC into their daily life (n=12, 63,2%), 84.2% (n=16) reported not finding CC difficult and 68.4% (n=13) found apps a helpful aid (*Table 1*).

Table 1: Participant Characteristics.

	n (%)
Gender	
Male	1 (5.3)
Female	18 (94.7)
Age	
20-30	3 (15.8)
31-40	6 (31.6)
41-50	5 (26.3)
51-60	4 (21.1)
61+	1 (5.3)
HbA1c mmol/mol (mean ±SD**)**	57 (±9.7)
Highest level of education received	
Junior Certificate	1 (5.3)
Leaving Certificate	6 (31.6)
Bachelor's degree	4 (21.1)
Higher Diploma	3 (15.8)
Masters	4 (21.1)
Doctorate	1 (5.3)
Duration of diabetes diagnosis	
0-5 years	1 (5.3)
6-10 years	2 (10.5)
11-15 years	0 (0)
16-20 years	2 (10.5)
21-25 years	5 (26.3)
26 years +	9 (47.4)
Duration of insulin pump therapy	
0-2 years	3 (15.8)
3-4 years	8 (44.4)
5-6 years	6(31.6)
7-8 years	1 (5.3)
9-10 years	0 (0)
11+ years	1 (5.3)

How long ago received carbohydrate counting training	
0-2 years	5 (27.8)
3-4 years	8 (44.4)
5-6 years	3 (16.7)
7-8 years	1 (5.6)
9-10 years	0 (0)
11+ years	1 (5.6)
Do you use nutritional labels as a guide to carbohydrate counting?	
Never	0 (0)
Sometimes	3 (15.8)
Daily	16 (84.2)
I don't know	0 (0)
When no nutritional labels are available, do you use a table detailing the carbohydrate content per 100g and relate to your portion size?	
Never	1 (5.3)
Sometimes	12 (63.2)
Daily	6 (31.6)
I don't know	0 (0)
When counting carbohydrates do you use measuring tools to estimate your portions? (e.g. measuring cups, scales, bowls spoons)	
Yes	14 (73.7)
No	5 (26.3)
Do you sometimes choose processed food to have access to the nutrition (facts) labels and to facilitate carbohydrate counting?	
Never	3 (15.8)
Sometimes	13 (68.4)
Regularly	1 (5.3)
I don't know	2 (10.5)
To what extent do you feel confident that you could incorporate carbohydrate counting into your daily life?	
Very confident	3 (15.8)
Confident	9 (47.4)
Moderately confident	6 (31.6)
A little confident	1 (5.3)
Not at all confident	0 (0)
Do you find mobile apps such as carbs and cals, my fitness pal useful when carbohydrate counting?	
Yes	13 (68.4)
No	6 (31.6)
Do you find carbohydrate counting difficult?	
Yes	3 (15.8)
No	16 (84.2)

Carbohydrate Counting Accuracy

The highest number of individual food items correctly estimated was 7 out of the 15 meals, with 1 food item being correctly estimated being the lowest score. The chicken curry and rice was incorrectly estimated by all participants: 78.9% (n=15) underestimating the carbohydrate content, with the remaining over estimating. The carbohydrate content of the cheese portion was correctly estimated by 14 of the 19 participants (73.7%) (*Table 2*).

A Pearson product-moment correlation was run to determine the relationship between CHO counting score and HbA1c. There was a very weak, negative relationship between CHO counting score and HbA1c level, which was not statistically significant (r= -.196, n=19, p=0.4).

Table 2: Carbohydrate Counting Test.

Meal/Snack	**Actual CHO content (g)**	**Mean estimated CHO content (g±SD)**	**Overestimated n (%)**	**Underestimated n (%)**
1: Chicken curry & rice	81	64.0 ± 30.6	4 (21.1)	15 (78.9)
2: Wholemeal baguette	58	54.7 ± 15.1	6 (31.6)	13 (68.4)
3: Spaghetti bolognaise & glass of milk	80	72.4 ± 33.5	4 (21.1)	15 (78.9)
4: Apple	21	14.8 ± 6.1	1 (5.31)	18 (94.7)
5: ½ pizza	50	73.4 ± 65.0	11 (57.9)	8 (42.1)
6: Ham salad	0	4.5 ± 6.9	6 (31.6)	13 (68.4)
7: Goujons & chips	90	73.4 ± 16.8	2 (10.5)	17 (89.5)
8: Porridge	19	36.2 ± 14.7	16 (84.2)	2 (10.5)
9: Scone with butter & jam	66	55.8 ± 17.1	3 (15.8)	16 (84.2)
10: Wrap	30	37.2 ±13.3	9 (47.6)	10 (.6)
11: Scrambled eggs	0	2.1 ± 2.9	7 (36.8)	12 (63.2)
12: Cheese portion	0	1.4 ± 2.8	5 (26.3)	14 (73.7)
13: 2 finger kitkat & cup of tea	13	17.2 ± 4.9	14 (73.7)	5 (26.3)
14: Cereal bar	25	30.8 ± 13.3	10 (52.6)	9 (47.4)
15: Banana	27	30.6 ± 8.9	5 (26.3)	14 (73.7)

Views about carbohydrate counting

Sixteen patients (84.3%) report finding fat/calorie dense meals difficult to assess correctly. In addition, 26.3% (n=5) reported not having access to a healthcare professional to help them revise CC, the same % felt it was deleterious to the management of their diabetes while 42.1% (n=8) felt their blood sugars fluctuated a lot even when using CC (*Table 3*).

Table 3: Views about carbohydrate counting.

	Strongly Agree n (%)	**Agree n (%)**	**Don't Disagree or Agree n (%)**	**Disagree n (%)**	**Strongly Disagree n (%)**
You do not have access to a health professional to help you revise carbohydrate counting	3 (15.8)	2(10.5)	2(10.5)	3(15.8)	9(47.4)
You do not have the time to do it	0(0)	4(21.1)	3(15.8)	7(36.8)	5(26.3)
It prevents you from having variety in your diet	1(5.3)	1(5.3)	1(5.3)	9(47.4)	7(36.8)
It complicates the management of your diabetes	0(0)	5(26.3)	2(10.5)	4(21.1)	8(42.1)
You feel like your blood sugars fluctuates a lot even if you count your carbohydrates	1(5.3)	7(36.8)	3(15.8)	5(26.3)	3(15.8)
You find fat/calorie dense meals (such as fast food, pizza,) hard to account for	4(21.1)	12(63.2)	1(5.3)	1(5.3)	0(0)
It takes too much time and delays the beginning of your meal	1(5.3)	6(31.6)	2(10.5)	8(42.1)	2(10.5)
Do you purposely avoid eating out as you find carbohydrate counting too stressful?	0(0)	3(15.8)	1(5.3)	6(31.6)	9(47.4)
Feel overwhelmed by the demands of living with diabetes	1(5.3)	6(31.6)	2(10.5)	4(21.1)	6(31.6)

Eating out

Eight patients (42.1%) of individuals report avoiding certain foods when eating out as they are not confident in calculating the carbohydrate content, and over one in five (n=4, 21.1%) felt stressed when choosing what to eat. However, the majority (n=13, 68.4%) do not appear to have an issue with asking staff questions regarding the ingredients used in particular meals (*Table 4*).

Table 4: Carbohydrate counting and eating out.

	Strongly Agree n (%)	**Agree n (%)**	**Don't Disagree or Agree n (%)**	**Disagree n (%)**	**Strongly Disagree n (%)**
Find it difficult to carbohydrate count	0(0)	7(36.8)	6(31.6)	5(26.3)	1(5.3)
Feel embarrassed to ask staff questions regarding the ingredients used in the meals	0(0)	3(15.8)	3(15.8)	8(42.1)	5(26.3)
Avoid certain foods as you cannot gauge the carbohydrate content	2(10.5)	6(31.6)	2(10.5)	5(26.3)	4(21.1)
Feel stressed when choosing what to eat	0(0)	4(21.1)	3(15.8)	8(42.1)	4(21.1)
Feel restricted in the types of food you can eat	0(0)	3(15.8)	2(15.8)	5(26.3)	8(42.1)

Discussion

This study reports poor competence in CC among people with type 1 diabetes using CSII pump therapy in Sligo University Hospital. Foods which were high in carbohydrates or had a carbohydrate content ≥50g (Chicken Curry, Spaghetti Bolognese, Goujons and Chips, Scone) tended to be underestimated. Similar findings were noted in a study conducted by Kawamura et al in Japan, where foods high in carbohydrate such as rice and noodle dishes were significantly underestimated[13].

In this study, foods which had little to no carbohydrates were more likely to be accurately estimated (ham salad, wrap, scrambled eggs, cheese, banana or yoghurt). However, the majority reported difficulty in assessing high fat and calorie dense meals. This is likely to be as a result of the complexity of distinguishing between calories and carbohydrate content of foods[14]. Of all the foods presented, porridge was the most significantly over estimated item as a total of 84.2% of the study group overestimated porridge with mean estimations of 36.2 ± 14.7g. This figure is almost two-fold greater than actual carbohydrate content of 19g. This overestimation could lead to the development of hypoglycaemia as a result of over administration of insulin. Overestimation however, is not uncommon among adults in CC. Meade et al demonstrated CC inaccuracies were predominantly due to overestimation with 82% of the study population unable to precisely quantify carbohydrates[15]. Teenagers and parents of children with T1D have also been renowned for misjudging carbs as current literature indicates that parents in particular tend to overestimate the carbohydrates in their children's meals by approximately 20%[16].

A major strength of this study is that it tested the knowledge of subjects when no nutritional labels were available. This would reflect real life situations such as when dining out or when consuming foods which did not have accompanying nutritional labels. Accurate quantification in this way can

allow for greater variety in the diet and can reduce uncertainties or limitations when choosing to eat out. Additionally, this study not only tested CC abilities of people with T1D but also investigated specific difficulties and concerns people had regarding CC. This information could be useful to diabetes educators who can address exact difficulties associated with CC and accordingly improve and tailor education strategies to better suit the target population.

Several limitations were noted throughout the study. Firstly, the small sample size (n=19) was a major limiting factor. Fewer participants can reduce the power of the study and so results should be interpreted with caution[17]. Testing for this study was exclusive to patients with T1D who were on CSII. It may have been of interest to include those with T1D who used MDI. The use of preselected foods can also be seen as a limitation in this study as the foods chosen may not adequately reflects the diets of the individuals who took part. Also, currently the use of apps and technology the availability of nutritional information have become more widespread. Therefore, those who rely on apps and nutritional labels on a daily basis may struggle to estimate carbohydrates in foods based on appearance alone when these resources are unavailable to them.

In conclusion, despite appropriate and comprehensive education in CC these skills decline with time and repeated interval education is important to allow accurate counting and appropriate dosing of insulin. We recommend the introduction of regular refresher courses within the healthcare setting to improve diabetes management.

Keywords: Carbohydrate counting, Type 1 diabetes, Structured education, Diabetes education, Insulin pump therapy, CSII

Declarations of Conflicts of Interest:
The authors declare no conflicts of interest.

Corresponding Author:
Laura Keaver
Department of Health and Nutritional Science,
Ash Lane,
Sligo,
F91 YW50.
Email: keaver.laura@itsligo.ie

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