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Research Article

Skills Lacking in Estimating Carbohydrate Content: A Need for Continual Education of Adults with Type 1 Diabetes

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ABSTRACT

Aim: To examine whether adults with type 1 diabetes (T1D) educated in counting carbohydrates can identify and correctly estimate the carbohydrate content, and to examine whether these skills are associated with lower glycated haemoglobin A1c (HbA1c).

Methods: Ninety-six patients with T1D on insulin pump therapy participated. We assessed skills in categorising 32 food items as either high- or low-carbohydrate and estimating carbohydrate portion sizes in 20 typical Danish high-carbohydrate food items. We calculated error estimates for carbohydrate portion sizes and examined patient characteristics with a likely impact on estimation accuracy.

Results: An average of 88% correct answers ranging from 21 to 100% were found for the high- or low-carbohydrate food items. The participants' estimations differed significantly from the correct carbohydrate content in 17 of 20 typical Danish high-carbohydrate food items. No significant associations were found between HbA1c and the ability to estimate carbohydrates correctly.

Conclusion: Although adults with T1D previously educated in basic carbohydrate counting can identify high-carbohydrate food items, they lack skills in correctly estimating carbohydrate portion sizes. Our results underline the need for continual education to strengthen and maintain skills in carbohydrate estimation.

Keywords: Type 1 diabetes mellitus, Glycaemic control, Carbohydrate counting, Carbohydrate estimation accuracy, Patient education

Introduction

The total amount of carbohydrates consumed in a meal is the major predictor of the postprandial glucose response [1,2]. Consequently, national and international clinical guidelines recommend that people with type 1 diabetes (T1D) learn basic carbohydrate counting (BCC) or similar experience-based methods as a meal-planning approach. BCC involves understanding the relationship between food and plasma glucose levels with special attention to the type, amount, and distribution of carbohydrate-containing foods [3,4].

Monitoring the carbohydrate intake is of paramount importance in the day-to-day regulation of especially postprandial blood glucose levels and thereby also long-term glycaemic control [5-10].

Studies have shown that children and adolescents with T1D tend to assess their intake of carbohydrates inaccurately and their lack of skills in estimating the carbohydrate content have been associated with higher blood glucose variability [11] and deteriorated glycated haemoglobin A1c (HbA1c) [12-14].

Not all Danish patients with T1D treated at outpatient clinics are referred to routine visits with a dietitian for nutritional education. However, in Denmark it is mandatory that all patients with T1D

receive education in BCC in a diabetes outpatient clinic before and after commencement of insulin pump therapy. This includes training skills in gram counting of carbohydrates and experience-based estimation of high-carbohydrate foods, so that patients gradually become more aware of how to estimate carbohydrate portion sizes accurately using their eyesight. We hypothesized that previously educated adults with T1D would be highly skilled in identifying carbohydrates and estimating carbohydrate content of foods.

The primary aim of the study was to investigate skills in BCC (i.e. identifying carbohydrate sources and estimating carbohydrate portion sizes) in adults with T1D on insulin pump therapy. The secondary aim was to examine whether skills in accurate estimation of carbohydrate content of foods are associated with lower HbA1c levels.

Materials and Methods

Participants

Adults with T1D from the outpatient clinic at Steno Diabetes Center Copenhagen were invited to participate in the study. All data were collected between April and June 2013. The inclusion criteria were adults (18–75 years) with T1D on insulin pump therapy and having attended at least one consultation with a dietician within the last two years. Exclusion criteria were carbohydrate counting naive, visually impaired and people diagnosed with T1D less than 12 months before beginning of the study. Informed consent to participate in the study was obtained from all participants according to Danish regulations. The study was a quality assurance project approved by the local ethics committee, the Danish Data Protection Agency which included an approval of an External Data Manager Agreement with the Capital Region for data storing.

Assessment of skills in BCC

Participants were asked to identify high- and low-carbohydrate sources by answering 'yes' or 'no' to whether 32 different food items contained an amount of carbohydrates which could affect their blood glucose. The 32 food items were shown on a computer screen as digital images and were developed and photographed according to practical guidelines from the National Food Institute at the Technical University of Denmark [15]. Subsequently, the participants were presented to a serving of real food and asked to estimate the carbohydrate content in grams in the presented serving without the use of aids. This procedure was repeated for 20 commonly consumed Danish foods high in carbohydrates. The study dietitians were responsible for portioning the correct amount of food (i.e. carbohydrates) in grams in each serving according to the curriculum for calculation of the error estimates.

Clinical data

Age, gender, diabetes duration, height and weight, HbA1c, number of years on insulin pump therapy and number of consultations with a dietician within the last two years were extracted from the patients' electronic medical records.

Statistical analysis

Differences between study participants and non-respondents were tested using the Mann-Whitney U test for numerical data while categorical data were compared by Pearson's Chi square test for differences in proportions.

The binomial data obtained from the participants' skills in identifying high-carbohydrate foods were assessed as percentages of correct and wrong answers for each of the 32 different food items. To assess estimation accuracy the participants' error estimates of carbohydrate portion sizes of the 20 servings of real food were calculated from the following equation:

Error estimate (g) = Estimated carbohydrate content (g) – Actual carbohydrate content (g)

A negative difference was considered to indicate underestimation of the presented food.

All error estimates were non-normally distributed and thus presented as medians with interquartile range (IQR). A One-sample Wilcoxon signed rank test was performed to test whether the participants' carbohydrate estimations differed significantly from the actual carbohydrate content of the 20 different food items. In addition, error estimates from participants who reported never or rarely eating the specific food were excluded in the analysis of differences between estimated and actual carbohydrate content.

The relationship between specific patient characteristics (age, gender, body mass index (BMI: kg/m^2), HbA1c) and the participants' overall accuracy level was determined. The participants' overall accuracy level was defined as accurate if they had a median estimation error within ±5g, as overestimated and underestimated with a median estimation error above 5g or below -5g, respectively. Differences between the three groups of participants were assessed using a Kruskal-Wallis H test for not-normally distributed data, one-way ANOVA for normally distributed data and by Pearson's Chi square test for differences in proportions for categorical data (gender).

For all statistical tests a two-sided significance level of $p < 0.05$ was used. All statistical analyses were performed with the SPSS software for Windows, version 22.0 (IBM Corp, Armonk, NY, USA.

Results

Twenty-eight % (n=96) of the 348 invited patients accepted to participate in the study (Table 1). The participants had a median age of 49 years (IQR 41-59), the median BMI was 26.0 kg/m^2 (IQR 23.0-29.0), and the median HbA1c was 7.5%, IQR 7.0-8.2 (59.0 mmol/mol, IQR 53.0-66.0). Median diabetes duration was 22 years (IQR 13-36) and median number of years on insulin pump therapy was 2.3 years (IQR 1-4). The participants had attended a median number of three consultations with a dietician within the last two years. The only difference between study participants and non-responders was an age difference of approximately 10 years ($p<0.001$, Table 1) in favor of the participants.

A very high percentage of correct answers was observed when the participants classified the 32 presented food items as either high- or low-carbohydrate sources. Cream was the only food with a high percentage of wrong answers (79%) compared with the other food items where the average of correct answers was 90% ranging from 54-100% (Figure 1).

As demonstrated in Table 2 the participants were only able to perform a correct estimation of the carbohydrate content in three of the 20 food items investigated (i.e. raisins, pizza, and boiled rice, Table 2). In 10 of the 20 food items the participants significantly overestimated the carbohydrate content, and in 7 of 20 they significantly underestimated estimated the carbohydrate content ($p<0.001$; Table 2).

Only age differed significantly between the three groups (accurate,

underestimation, or overestimation) categorised by their median accuracy level when estimating the 20 high-carbohydrate food items (p=0.014; Table 3).

Discussion

To our knowledge our study is the first to examine how skilled adults with T1D are in identifying and estimating high-carbohydrate foods (i.e. the concept of BCC). We found that adults with T1D were highly skilled in identifying commonly eaten high-carbohydrate foods but lacked skills in estimating the carbohydrate content correctly in 17 of 20 food servings of high-carbohydrate foods.

In addition to the high percentage of correct answers in identifying almost all high-carbohydrate food items, high percentages of wrong answers were only observed for cream and to a minor extent for walnuts, avocado, and pork crackling. These foods have relatively low carbohydrate content and a high content of dietary fat and thus the high percentages of wrong answers may reflect difficulties in distinguishing between foods' calorie content and carbohydrate content. A finding consistent with a study [16] where children with T1D accompanied by their parents, and adolescents with T1D also had a tendency to estimate the carbohydrate content inaccurately in foods with a low-carbohydrate/high-calorie content (and thus a high fat content). Another explanation for high percentages of wrong answers for cream, walnuts, avocado, and pork crackling maybe that

Table 1: Characteristics of study participants and non-responders.

Clinical characteristics	*n*	Participants	*n*	Non-responders	P-value
Gender (M/F), % (n)	96	45.8/54.2 (44/52)	252	32.9/67.1 (83/169)	0.026[a]
Age, y	96	49.0, 41.0-58.8	252	39.5, 30.0-48.0	<0.001[b]
BMI, kg/m^2	96	26.0, 23.0-29.0	250	25.0, 23.0-29.0	0.318[b]
HbA1c, %, IQR(mmol/mol)	96	7.5, 7.0-8.2 (59.0, 53.0-66.0)	252	7.5, 6.8-8.3 (59.0, 51.2-66.8)	0.804[b]
Years with diabetes, y	96	21.5, 13.0-35.8	247	23.0, 15.0-34.0	0.386[b]
Insulin pump therapy, y	96	2.3, 1.1-3.9	252	2.4, 1.0-4.0	0.941[b]
Total insulin dosage, IU	96	36.0, 27.0-49.5	252	38.0, 30.0-49.0	0.298[b]
No of dietician visitswithin the last 2 y	96	3.0, 1.0-5.0	252	2.0, 0.0-4.0	0.342[b]

BMI: body mass index; F: Female; M: Male; IU: International Unit; y: years. Data are medians, IQR: 25th-75th percentile or proportion (numbers); P < 0.05 significant using either Pearson's Chi square test for differences in proportions (a) or Mann-Whitney U test (b).

Table 2: Difference between estimated and actual carbohydrate content.

Food item	The actual carbohydrate content (gram)	*n*	Median estimation error of carbohydrate content (gram)	P-value
1. Grapes	5	96	5.0, 5.0-10.0	<0.001
2. Melon	24	96	6.0, 1.0-16.0	<0.001
3. Milk chocolate	10	96	5.0, 0.0-10.0	<0.001
4. Dark chocolate	15	96	10.0, 5.0-20.0	<0.001
5. Potato chips	25	96	5.0, -5.0-15.0	<0.001
6. Boiled potatoes	40	96	10.0, 0.0-20.0	<0.001
7. Boiled pasta	30	96	6.5, 0.0-15.0	<0.001
8. Pasta salad	40	96	5.0, 0.0-20.0	<0.001
9. Ice cream	30	96	10.0, 0.0-20.0	<0.001
10. Kidney beans	10	96	10.0, 10.0-20.0	<0.001
11. Raisins	25	96	-1.0, -5.0-5.0	0.118
12. Pizza	50	96	0.0, -10.0-10.0	0.744
13. Boiled rice	60	96	0.0, -10.0-20.0	0.475
14. Fruit pie	35	96	-5.0, -10.0-5.0	<0.001
15. Mixed candy	45	96	-10.0, -20.0-5.0	<0.001
16. Bun	30	96	-10.0, -10.0-(-5.0)	<0.001
17. Oatmeal	50	96	-10.0, -20.0-7.5	<0.001
18. Dried apricots	20	96	-5.0, -10.0-0.0	<0.001
19. Potato slices	60	96	-10.0, -15.0-3.8	0.007
20. Lasagne	70	96	-14.0, -28.8-(-5.0)	<0.001

= Overestimation = Accurate estimation = Underestimation

Data are medians, IQR: 25th-75th percentile;P< 0.05 significant using One-sample Wilcoxon signed rank test.

Table 3: Characteristics of participants categorised by their overall carbohydrate estimation accuracy level.

Clinical variable	*n*	Underestimated (median < - 5g)	Accuracy (median within ±5g)	Overestimated (median > 5g)	P-value
Participants, % (n)	96	10 (10)	67 (64)	23 (22)	-
Gender (M/F), % (n)	96	60/40 (6/4)	44/56 (28/36)	45/55 (10/12)	0.631[a]
Age, y	96	53.1 ±14.9	50.6 ±12.8	41.5 ±13.6	0.014[b]
BMI, kg/m^2	96	26.9 ±4.5	26.2 ±4.1	26.4 ±4.3	0.890[b]
HbA1c, %, IQR (mmol/mol)	96	7.7, 7.3-8.2 (60.5, 56.0-66.5)	7.4, 7.0-8.0 (57.5, 53.0-64.0)	8.1, 7.1-8.6 (64.5, 54.0-71.0)	0.169[c]
Years with diabetes, y	96	35.0, 17.3-41.8	20.5, 12.5-34.3	21.0, 14.5-37	0.408[c]
Insulin pump therapy, y	96	1.4, 0.7-2.5	2.3, 1.1-3.8	2.7, 1.5-4.3	0.369[c]
Total insulin dosage, IU	96	40.5, 29.0-53.3	33.5, 26.0-44.0	43.5, 33.8-56.0	0.087[c]
No of dietician visits within the last 2 y	87	3.0, 0.0-4.3	3.0, 1.0-4.5	3.0, 0.0-6.3	0.910[c]

F:Female; M: Male; IU: International Unit; y: years. Data are medians, IQR: 25th-75th percentile, mean ±SD or proportion (numbers); P < 0.05 significant using either Pearson's Chi square test for differences in proportions (a), one-way ANOVA (b) or Kruskal-Wallis H test (c).

these foods are not that frequently eaten compared with lasagne, banana, rye bread, pasta, biscuit, and potatoes – food items that all participants were able to identify as high-carbohydrate containing food items. Interestingly, lasagne was also the food item that our participants underestimated the most with a median error of 14g in estimated vs. actual carbohydrate content. The reason is probably the relative complexity of lasagne, which in many ways can be considered as a mixed meal since it consists of several ingredients. This might have influenced the participants' ability to estimate the high-carbohydrate ingredient (i.e. the pasta sheets) resulting in an underestimation of the carbohydrate content. Challenges with mixed meals complicating the ability to estimate carbohydrates is consistent with a study [12] in which adolescents with T1D significantly under- or overestimated the carbohydrate content when foods were presented as mixed meals.

We also observed contrasting results for boiled and sliced potatoes which most of our participants mainly over- and underestimated, respectively. Although potatoes intuitively appear easy to assess (i.e. the number and size of the potatoes) the irregular shape of the not-separated potato slices may influence the perception of the portion size [17,18] and hence complicate the assessment of the total carbohydrate content presented [19]. Another pitfall in relation to potatoes is that the carbohydrate content increases approximately by one third when potatoes are being sliced and prepared in the oven as compared to boiled potatoes [20]. The difficulties in our study in estimating portion sizes of potatoes is, however, consistent with previous studies when the potatoes were presented either as whole potatoes [17,21] or as potato slices [16].

We found that the majority of all food items in the present study were significantly over- or underestimated, which is in line with two previous studies reporting that adolescents with T1D over- or underestimated all the presented food items with 47-55% and 17-25%, respectively [12,13]. Other studies also confirm a high prevalence of carbohydrate estimation inaccuracy in adults with T1D who either underestimated 63% of all meals with more than 20% of the actual carbohydrate content [11] or 82% of all patients overestimated the carbohydrate content by 40% in average [22]. In contrast to our study and others [11-13,22] that rigorously reported the level of over- and underestimation, several studies have not quantified the degree of accuracy but only concluded that the participants estimated the carbohydrate content accurately [14,23,24] or that large variations in estimations were observed [25].

In relation to glycaemic control we did not find any significant difference in HbA1c between participants across categories of overall accuracy level. Still, the group with an accurate carbohydrate estimation (median estimation error within ±5g) had the lowest HbA1c (7.4%, 57.5 mmol/mol) compared with the group which underestimated (HbA1c 7.7%, 60.5 mmol/mol) or the group which overestimated the overall accuracy level (HbA1c 8.1%, 64.5 mmol/mol). Our result is consistent with a previous randomised control trial [12] in which no difference in HbA1c was found between adolescents who did and did not estimate carbohydrates correctly. In contrast, other studies confirm a significantly lower HbA1c in children who had good knowledge about carbohydrate counting [26] and in adolescents who estimated the carbohydrate content in dinner meals accurately [13]. However, in the latter study, HbA1c was not significantly different between adolescents when a whole day's intake including lunch and snacks were assessed. Several other studies did not find any differences in HbA1c in adults who obtained a high carbohydrate accuracy test score [22], or attended a carbohydrate counting training program [24], or when children (accompanied by caregivers) and adolescents estimated carbohydrates accurately [27]. Clearly, lack of consensus exists among studies focusing on carbohydrate counting and its effect on HbA1c. In addition, the lack of standardisation in determining estimation accuracy is inconvenient in studies focusing on portion size assessment and it remains difficult to compare results between studies and thus prove the clinically importance of educating patients in estimating the carbohydrate content accurately for obtaining optimal glycaemic control. Thus, our cut-off for estimation accuracy might be a limitation (less than ±5g of the actual carbohydrate content) since this definition equate a participant with an estimation error of i.e. ±6g with one making estimation errors of i.e. ±50g – estimation errors with very different impact on blood excursions and hence the risk of complications. Our cut-off for estimation accuracy has been applied in previous studies [13,22], but other definitions of carbohydrate estimation accuracy have also been used [12,16]. Two studies [28,29] have found that carbohydrate estimations within 10 grams of the actual carbohydrate content in a meal are sufficient to maintain a postprandial blood glucose within the target range in children and adolescents with T1D and thus argue in favour of

a cut-off for estimation accuracy of 10g instead of 5g. Nevertheless, we used a cut-off of 5g for our participants since they are advised to take additional mealtime insulin to cover carbohydrate intake as low as 5g due to the flexibility and ease of insulin matching with an insulin pump and the effect on glycaemic control with more tight insulin-to-carbohydrate matching. In addition, our participants had been trained by a skilled dietician in correct carbohydrate estimation before receiving an insulin pump as compared to other people with T1D to whom this training is still not part of the standard dietary treatment. However, at the time when the study was conducted we did not offer our patients the same intensive education and hands-on training in BCC including carbohydrate estimation as we do today, but again this intensive hands-on training is still not part of the routine nutrition education at outpatient diabetes clinics in Denmark or abroad and we are currently examining the effect on glycaemic control in a randomized controlled trial with adults with T1D on MDI therapy with a basal-bolus insulin regime [30]. Nevertheless, the preliminary results in this observational exploratory study indicate that the observed estimation errors can be explained by inadequate carbohydrate estimation skills despite some training in BCC.

Another limitation of our study is the included pre-weighted portion sizes of pre-selected foods since the selected food items, as well as the presented portion sizes, may have deviated from the participants' usual dietary habits, thereby influencing the participants' skills in estimating the presented portion sizes correctly. Nevertheless, we did try to take this into account by recording information about the participants' eating frequency of the presented food items and excluding carbohydrate estimates from participants who reported never or rarely eating the specific food item.

Certainly, we have demonstrated that carbohydrate counting is a difficult task [31] which emphasizes the need for continual assessment of skills and repeatedly delivering nutrition education and support in carbohydrate counting in people with T1D to achieve and maintain skills in correct carbohydrate counting estimation [3]. See Table 1 in [32] for data on the use of a simple tool for assessment of carbohydrate estimation skills in adults with T1D [32].

Conclusion

We found that adults with T1D are very good at distinguishing between food items with or without carbohydrates but do not have a similar ability to accurately estimate carbohydrate portion sizes. The participants in our study who assessed carbohydrate content with the highest accuracy (within 5g) tended to have the lowest HbA1c. Our results underline the importance of continual education of people with T1D in BCC by skilled dieticians.

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References

1. Evert, AB., Boucher, JL., Cypress, M., Dunbar, SA., Franz, MJ., Mayer-Davis, EJ., et al. (2013) Nutrition therapy recommendations for the management of adults with diabetes. Diabetes Care, 36(11): 3821-3842.
2. Sheard, NF., Clark, NG., Brand-Miller, JC., Franz, MJ., Pi-Sunyer, FX., Mayer-Davis, E., et al. (2004) Dietary carbohydrate (amount and type) in the prevention and management of diabetes: a statement by the american diabetes association. Diabetes Care, 27(9): 2266-2271.
3. Evert, AB., Boucher, JL., Cypress, M., Dunbar, SA., Franz, MJ., Mayer-Davis, EJ., et al. (2013) Nutrition Therapy Recommendations for the Management of Adults With Diabetes. Diabetes Care, 36(11): 3821-3842.
4. (2015) Standards of Medical Care in Diabetes—2015. Diabetes Care 38 (Supplement 1): 93.
5. Fitzsimons, B., Wilton, L., Lamont, T., McCulloch, L., Boyce, J. (2002) The Audit Commission review of diabetes services in England and Wales, 1998-2001. Diabet Med, 19: 73-78.
6. Gorst, C., Kwok, CS., Aslam, S., Buchan, I., Kontopantelis, E., Myint, PK., et al. (2015) Long-term Glycemic Variability and Risk of Adverse Outcomes: A Systematic Review and Meta-analysis. Diabetes Care, 38(12): 2354-2369.
7. Group, DS. (2002) Training in flexible, intensive insulin management to enable dietary freedom in people with type 1 diabetes: dose adjustment for normal eating (DAFNE) randomised controlled trial. BMJ, 325(7367): 746.
8. Scavone, G., Manto, A., Pitocco, D., Gagliardi, L., Caputo, S., Mancini, L., et al. (2010) Effect of carbohydrate counting and medical nutritional therapy on glycaemic control in Type 1 diabetic subjects: a pilot study. Diabet Med, 27(4): 477-479.
9. Dias, VM., Pandini, JA., Nunes, RR., Sperandei, SL., Portella, ES., Cobas, RA., et al. (2010). Effect of the carbohydrate counting method on glycemic control in patients with type 1 diabetes. Diabetol Metab Syndr, 2: 54.
10. Laurenzi, A., Bolla, AM., Panigoni, G., Doria, V., Uccellatore, A., Peretti, E., et al. (2011). Effects of carbohydrate counting on glucose control and quality of life over 24 weeks in adult patients with type 1 diabetes on continuous subcutaneous insulin infusion: a randomized, prospective clinical trial (GIOCAR). Diabetes Care, 34(4): 823-827.
11. Brazeau, AS., Mircescu, H., Desjardins, K., Leroux, C., Strychar, I., Ekoe, JM., et al. (2013) Carbohydrate counting accuracy and blood glucose variability in adults with type 1 diabetes. Diabetes Res Clin Pract, 99(1): 19-23.
12. Spiegel, G., Bortsov, A., Bishop, FK., Owen, D., Klingensmith, GJ., Mayer-Davis, EJ., et al. (2012) Randomized Nutrition Education Intervention to Improve Carbohydrate Counting in Adolescents with Type 1 Diabetes Study: Is More Intensive Education Needed? J Acad Nutr Diet, 112(11): 1736-1746.
13. Bishop, FK., Maahs, DM., Spiegel, G., Owen, D., Klingensmith, GJ., Bortsov, A., et al. (2009) The Carbohydrate Counting in Adolescents With Type 1 Diabetes (CCAT) Study. Diabetes Spectrum, 22(1): 56-62.
14. Mehta, SN., Quinn, N., Volkening, LK., Laffel, LM. (2009) Impact of carbohydrate counting on glycemic control in children with type 1 diabetes. Diabetes Care, 32(6): 1014-1016.
15. Nielsen, TH., Biltoft-Jensen, A., Ygil, KH. (2011) Udvikling af billedserier til Den nationale undersøgelse af danskernes kostvaner og fysiske aktivitet 2011. DTU National Food Institute. [cited 2019 May 5]. Retrieved from: https://www.food.dtu.dk/-/media/Institutter/Foedevareinstituttet/Publikationer/Pub-2011/Billedserier-til-Den-nationale-undersoegelse-af-danskernes-kost-og-fysiske-aktivitet-2011.ashx?la=da&hash=4AB292950FC3E66FD1EACBDC36327B5344B84A55
16. Kawamura, T., Takamura, C., Hirose, M., Hashimoto, T., Higashide, T., Kashihara, Y., et al. (2015) The factors affecting on estimation of

carbohydrate content of meals in carbohydrate counting. Clin Pediatr Endocrinol, 24(4): 153-165.

17. Nelson, M., Atkinson, M., Darbyshire, S. (1994) Food photography. I: The perception of food portion size from photographs. Br J Nutr, 72(5): 649-663.

18. Lucas, F., Niravong, M., Villeminot, S., Kaaks, R., Clavelchapelon, F. (1995) Estimation of food portion size using photographs - validity, strengths, weaknesses and recommendations. Journal of Human Nutrition and Dietetics, 8(1): 65-74.

19. Nelson, M., Haraldsdottir, J. (1998) Food photographs: practical guidelines II. Development and use of photographic atlases for assessing food portion size. Public Health Nutr, 1(4): 231-237.

20. Andersen, LT., Haraldsdóttir, J. Forskningsinstitut for Human Ernæring Kgl. Veterinær- og Landbohøjskole (1996). Typiske vægte for madvarer. Scand J Nutr, 40 (4): S129-152.

21. Timon, CM., Cooper, SE., Barker, ME., Astell, AJ., Adlam, T., Hwang, F., et al. (2017) A comparison of food portion size estimation by older adults, young adults and nutritionists. Journal of Nutrition, 7.

22. Meade, LT., Rushton, WE. (2016) Accuracy of Carbohydrate Counting in Adults. Clin Diabetes, 34(3): 142-147.

23. Nebel, IT., Blüher, M., Starcke, U., Müller, UA., Haak, T., Paschke, R. (2002) Evaluation of a computer based interactive diabetes education program designed to train the estimation of the energy or carbohydrate contents of foods. Patient Education and Counseling, 46(1): 55-59.

24. Bruttomesso, D., Pianta, A., Crazzolara, D., Capparotto, C., Dainese, E., Zurlo, C., et al. (2001) Teaching and training programme on carbohydrate counting in Type 1 diabetic patients. Diabetes Nutr Metab, 14(5): 259-267.

25. Ahola, AJ., Makimattila, S., Saraheimo, M., Mikkila, V., Forsblom, C., Freese, R., et al. (2010). Many patients with Type 1 diabetes estimate their prandial insulin need inappropriately. J Diabetes 2(3): 194-202.

26. Koontz, MB., Cuttler, L., Palmert, MR., O'Riordan, M., Borawski, EA., McConnell, J., et al. (2010) Development and validation of a questionnaire to assess carbohydrate and insulin-dosing knowledge in youth with type 1 diabetes. Diabetes Care, 33(3): 457-462.

27. Smart, CE., Ross, K., Edge, JA., King, BR., McElduff, P., Collins, CE. (2010) Can children with Type 1 diabetes and their caregivers estimate the carbohydrate content of meals and snacks? Diabet Med, 27(3): 348-353.

28. Smart, CE., Ross, K., Edge, JA., Collins, CE., Colyvas, K., King, BR. (2009) Children and adolescents on intensive insulin therapy maintain postprandial glycaemic control without precise carbohydrate counting. Diabet Med, 26(3): 279-285.

29. Smart, CE., King, BR., McElduff, P., Collins, CE. (2012) In children using intensive insulin therapy, a 20-g variation in carbohydrate amount significantly impacts on postprandial glycaemia. Diabet Med, 29(7): e21-e24.

30. Ewers, B., Andersen, HU., Vilsbøll, T., Bruun, JM. (2019) The dietary education trial in carbohydrate counting (DIET-CARB Study): study protocol for a randomised, parallel, open-label, intervention study comparing different approaches to dietary self-management in patients with type 1 diabetes. BMJ Open, 9.

31. Elwood, PC., Bird, G. (1983) A photographic method of diet evaluation. Hum Nutr Appl Nutr, 37(6): 474-477.

32. Schouw, N., Skouboe, AG., Bruun, JM., Ewers, B. (2019) Validation Data Based On A Web-Based Photographic Questionnaire For Assessment Of Skills In Estimating Carbohydrate Portion Sizes In Adults With Type 1 Diabetes. J Clin Nutr Food Sci, 2(2): 54-056.