Functional insulin therapy: relationship to carbohydrate intake

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Conflict of interests

Merck Sharp & Dohme, Novo Nordisk, Novartis, Boehringer Ingelheim, Sanofi, Takeda, Lilly, Astra Zeneca, Lifescan, Medtronic
Basal/Bolus insulin treatment with rapid-acting and long-acting analogs or pumps

Plasma insulin

Aspart
Lispro
Glulisin

8:00  12:00  16:00  20:00

Time

Glargine Detemir
DCCT study

![Graph showing the relationship between HbA1c (%), risk of retinopathy per 100 patient years, and severe hypoglycaemia per 100 patient years.](image)

Postprandial hyperglycaemia is a major source of blood glucose variability.
Goals of Functional insulin therapy (FIT)

- normoglycemia (HbA1c < 6.5%)
- no hypos
- flexible eating (dietary freedom)
FIT knowledge

1. Functional insulin replacement
   All about insulins
   Comprehension: basal bolus, prandial, correction bolus
   Insulin dose adjustment

2. Tests of basal insulin, Carb factor, correction factor

3. Functional insulin replacement
   under special conditions (exercise, illness...)
Carbohydrate Counting and Diabetes
Why Carb Count?

• Need some methodology on which to base rapid-acting insulin dosing with meals/snacks

• Can allow for more flexibility with eating for people with type 1 diabetes

• Theoretically, should better match insulin bolus to carb intake and result in reduced post-prandial hyper- and hypoglycemia
Benefits of Adjusting Insulin for Carbohydrates

- Allows More Flexibility
  - No need to stay within carb ranges for meals
  - For patients on pump therapy or MDI eating schedule can be much more flexible
- More Advanced Form of Diabetes Management
- Potential for more accurate dosing
- Pump therapy requires carb input
Estimating CHO

- Weighing food
- Measuring using cups & spoons
- Food labels
- Recipes that list CHO content
- CHO Counting tables/books
How many Carbs?

1 cup tossed salad greens
1 small dinner roll
3 meat balls
1 cup pasta
Wine* - 5 oz
2 Tbsp. Salad dressing

Wine: 0 grams
Meat balls: 0 grams
Pasta w/ tomato sauce: 30 grams
Dinner roll: 15 grams
Salad greens: 0 grams
Salad dressing: + 0 grams

TOTAL = 45 grams or 3 choices

* According to the ADA, “If adults with diabetes choose to use alcohol, daily intake should be one drink per day or less for adult women and two drinks per day or less for adult men.”
Food Labels

- Locate Serving Size
- Locate total grams of carbohydrate
- Rules for fiber and sugar alcohols
Fiber and Sugar Alcohols

• For example:

  Total Carbohydrate  30 grams
  Dietary Fiber       10 grams

  30 grams (Total Carbohydrate)
  - 5 grams  (half of dietary fiber)
  25 grams of Carb to count

• The same rule applies for sugar alcohol
Figure A: Relationship of meal carbohydrate intake, insulin bolus, and post-prandial glycemic elevations

Glucose concentration mg/dl

180 mg/dl

Goal: reduction of post-prandial hyperglycemia

Meal and insulin bolus

70 mg/dl

Time

undertreatment

Overtreatment with hypoglycemia
Calculating a Dose

3 Step Process

1^{st} Step: Insulin to Carb Ratio
Determine how much insulin is needed for carbs eaten at meal or snack:
- Count up total carb grams
- Divide total grams by ratio
Calculating a Dose

2nd Step: Blood Glucose Correction
Determine How Much Insulin is Needed to correct blood sugar (bg) to target
➢ Check bg
➢ Calculate insulin amount needed to bring bg into target range (i.e. ... 1 unit per 50 over 150- Individualized)

3rd Step: Total Dose = Insulin needed for carbs plus insulin needed for bg
Estimation of prandidal insulin

- **Rule of 500: Carb factor**

\[
500 : \text{TDD} = \text{g Carbs} " \text{covered} " \text{ by 1Units short acting analogue insulin}
\]

Example:
CDO = 25 U
\[
500 : 25 = 20 \quad \Rightarrow \quad \text{1 E covered 20 g Carbs}
\]
How to calculate insulin dose by counting Grams of Carbs

Insulin prescribed by MD:

“1 unit of insulin for every 15 grams of Carb”

1 burger patty + 1 hamburger bun + ½ cup peas + 1 small apple

• How many grams of Carb is in this meal?
  60

• How many units of insulin are needed?
  60 grams of Carb ÷ 15 = 4 units of insulin
The evidence...

- **DAFNE study**: course teaching flexible intensive insulin treatment combining with dietary freedom and insulin adjustment
  - Improved A1c at 6 months (9.4% v. 8.4%, p<0.0001)
  - Improved ‘quality of life’ at one year

- **DCCT study**: using CHO/insulin ratios in intensively treated group improved glycemic control
The aim of the programme is for participants to eat freely, and adjust their insulin to match carbohydrate load, physical activity and insulin sensitivity.
DAFNE
Dose Adjustment For Normal Eating

• A course adapted from the Michael Berger’s ‘Diabetes Training and Treatment Programme’ for people with Type 1 diabetes and started in the UK from 2000.

• Intensive group education taking place over 5 consecutive days with a skills based focus.

• Led by Diabetes Specialist Nurse and Dietitian.

• Normally 6 to 8 participants per group.
## DAFNE timetable

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.15 - 09.45 Introduction</td>
<td>09.15 - 10.30 Discussion:</td>
<td>09.15 - 10.30 Group discussion:</td>
<td>09.15 - 10.30 Group discussion:</td>
<td>09.15 - 10.30 Group discussion:</td>
</tr>
<tr>
<td></td>
<td>Individual blood glucose levels</td>
<td>Glucose levels</td>
<td>Glucose levels</td>
<td>Glucose levels</td>
</tr>
<tr>
<td>09.45 - 10.45 What is diabetes?</td>
<td>10.30 - 10.45 Coffee</td>
<td>10.45 - 12.30 Hypoglycaemia</td>
<td>10.45 - 12.30 Nutrition 4</td>
<td>10.45 - 11.45 Sick day rules</td>
</tr>
<tr>
<td></td>
<td>10.45 - 12.30 DAFNE insulin adjustment</td>
<td>10.45 - 12.30 Nutrition 4</td>
<td>10.45 - 12.30 Nutrition 4</td>
<td>11.45 - 12.30 Social aspects</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>10.45 - 11.00 Coffee</td>
<td>10.30 - 10.45 Coffee</td>
<td>10.30 - 10.45 Coffee</td>
<td>10.30 - 10.45 Coffee</td>
<td>10.30 - 10.45 Coffee</td>
</tr>
<tr>
<td>11.00 - 12.30 Nutrition 1</td>
<td>10.45 - 12.30</td>
<td>10.45 - 12.30</td>
<td>10.45 - 12.30</td>
<td>10.45 - 11.45</td>
</tr>
<tr>
<td>• Identify carbohydrates</td>
<td>DAFNE insulin adjustment</td>
<td>Hypoglycaemia</td>
<td>Nutrition 4</td>
<td>Sick day rules</td>
</tr>
<tr>
<td>13.30 - 15.00 All about insulin</td>
<td>13.30 - 15.00</td>
<td>13.30 - 15.00</td>
<td>13.30 - 15.00</td>
<td>13.30 - 14.30</td>
</tr>
<tr>
<td></td>
<td>Nutrition 2</td>
<td>Nutrition 3</td>
<td>Annual review and screening</td>
<td>Quiz</td>
</tr>
<tr>
<td></td>
<td>• Putting carbohydrate estimation into practice</td>
<td>• Food packaging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.00 - 15.15 Coffee</td>
<td>15.00 - 15.15 Coffee</td>
<td>15.00 - 15.15 Coffee</td>
<td>15.00 - 15.15 Coffee</td>
<td>Close</td>
</tr>
<tr>
<td>15.15 - 17.00 New insulin regime and individual targets</td>
<td>15.15 - 16.15 Self monitoring</td>
<td>15.15 - 16.15 Managing physical activity</td>
<td>15.15 - 16.15 Questions for the Doctor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16.15 - 17.00 Discussion:</td>
<td>15.15 - 16.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Individual blood glucose levels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.15 - 17.00 Group dose adjustment session</td>
<td>16.15 - 17.00</td>
<td>16.15 - 17.00</td>
<td></td>
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</tr>
</tbody>
</table>
UK DAFNE Study

n=144 pts in 3 UK centres

HbA1c (%)

Beginning 6 months 12 months

Immediate DAFNE

Delayed DAFNE

DAFNE study group. BMJ 2002
Results: DTSQ

- Immediate DAFNE
- Delayed DAFNE

p<0.0001

DAFNE study group. BMJ 2002
How does it work in our center?
**DIABETES FACTS**

**Population:** 135,000  
**Type 1 DM:** 6,000  
**Prevalence:** 6.9%  

**Population:** 2,054,199  
**Area:** 20,273 km²
• Started in 2003
• 1440 type 1 diabetic pts.
• Age 18-65

• Education taking place over 3 consecutive days.
• Normally 3-4 participants per group.

• Offered to anyone who needs/wants to improve self-management skills.
• Offered to all newly-diagnosed patients.

• Led by diabetes specialist nurse and diabetologist.
• N= 180 pts
• mean age 38±10y
• duration diabetes 17±10y

• Hba1c 8.23 ± 0.8% ( 3 values 1 year before FIT)

• 3 values of HbA1c 1 year after FIT

Effect of FIT on HbA1c

Effect of FIT on severe hypoglycemia

Effect of FIT on total daily insulin dose

Total daily insulin dose (Units)

- Before FIT: 42.37
- After FIT: 40.71

p < 0.05

Continuous Subcutaneous Insulin Infusion in Adult Type 1 Diabetes Mellitus: Data from a Registry at the University Medical Centre Ljubljana, Slovenia

TABLE 1:
Demographic and clinical characteristics of patients with type 1 diabetes who were treated with continuous subcutaneous insulin infusion (CSII) and included in the present comparison of CSII with multiple daily injection (MDI) insulin treatment (n = 184)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CSII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at initiation of CSII, years</td>
<td>39.4 ± 10.7</td>
</tr>
<tr>
<td>Diabetes duration prior to CSII, years</td>
<td>15.7 ± 9.4</td>
</tr>
<tr>
<td>CSII duration, years</td>
<td>3.8 ± 0.3</td>
</tr>
<tr>
<td>Body weight, kg</td>
<td>73.2 ± 14.8</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>25.9 ± 5.6</td>
</tr>
<tr>
<td>Indication for starting CSII</td>
<td></td>
</tr>
<tr>
<td>Insufficient glycaemic control</td>
<td>79 (43)</td>
</tr>
<tr>
<td>Trying to conceive/pregnant</td>
<td>52 (28)</td>
</tr>
<tr>
<td>Unawareness of hypoglycaemia</td>
<td>46 (25)</td>
</tr>
<tr>
<td>Dawn phenomenon</td>
<td>7 (4)</td>
</tr>
</tbody>
</table>

Data presented as mean ± SD, or n (%) of patients.

TABLE 3:
Glycosylated haemoglobin (HbA₁c) levels and total daily insulin dose over a period of 3 years in patients with type 1 diabetes after changing from multiple daily injection (MDI) insulin therapy to continuous subcutaneous insulin infusion (CSII) (n = 184)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>MDI</th>
<th>After 1 year</th>
<th>After 2 years</th>
<th>After 3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>HbA₁c, %</td>
<td>7.6 ± 0.9</td>
<td>6.9 ± 0.9***</td>
<td>6.9 ± 0.6***</td>
<td>7.0 ± 0.6***</td>
</tr>
<tr>
<td>Total insulin, IU/day</td>
<td>48.9 ± 16.2</td>
<td>38.5 ± 15.3***</td>
<td>38.7 ± 12.3***</td>
<td>38.1 ± 14.4***</td>
</tr>
</tbody>
</table>

Data presented as mean ± SD.
***p < 0.001 versus MDI (Student’s t-test).
Use of bolus calculator reduces postprandial blood glucose

\[ p < 0.001 \]

10.5 ± 2.0

9.2 ± 1.4

36 type 1 diabetic patients randomised to bolus calculator or usual meal bolus dosing for 2 weeks

Integrated bolus calculators in insulin pumps

- Introduced in 2002

- Calculate bolus dose based on:
  - Premeal BG
  - Target BG
  - Intended CHO intake
  - I:C ratio and ISF
  - Insulin ‘on board’ or active insulin (amount remaining from previous bolus)
Timing of meal-time bolus

Most patients using CSII with monomeric insulin give meal insulin bolus at start of meal or even after meal.
Bolus 20 min prior to meal reduces postprandial hyperglycaemia

23 type 1 DM patients using CSII with glulisine

Cobry et al Diabetes Technol Ther 2010; 12: 173-177
Giving meal insulin bolus
~15-20 min before meal start
improves control in many patients
Influence of food type

Fatty meals
High fat meals delay gastric emptying and may cause insulin resistance and late hyperglycaemia.
Bolus types

- Standard or single bolus
- Two boluses
- Extended or square wave
- Dual or combination wave
Dual-wave bolus reduces postprandial hyperglycaemia after a fatty meal

24 type 1 DM subjects
Ate pizza for evening meal
Std bolus, 4-h, 8-h dual wave
CGM used to track glucose

Jones SM et al. Diabetes Technol Ther 2005; 233-239
Moje zdravje

Rekreacije

Kolesarjenje - 120 min
Tenis - 60 min

Rekreacija

Kdaj: 22:06
Aktivnost: Pohodništvo
Trajanje: 01:00
Zahtevnost: Lahka

Moje zdravje

Statistika hrane

Zadnjih 7 dni
Conclusions...

• All people with Type 1 diabetes (also type 2 with basal-bolus therapy) should be offered a structured FIT education course.

• Carbohydrate counting is an important skill for all involved.

• FIT outcomes: lower HbA1c, no increase or even reduced severe hypos, better QoL.
Thank you !