Management of Type 2 Diabetes: Diet Composition and Blood Glucose

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Highland Diabetes Symposium 2014; Inverness
Background

Outcome of the IDF report

- post-meal glucose is harmful and should be addressed
- implement strategies to lower post-meal glucose
- consider nutritional, as well as pharmacological therapies

“evidence for controlling post-meal glucose by nutritional means”
Dietary Composition

- major macronutrients: carbohydrate, protein, and fat
- micronutrient vitamins and minerals
- non-nutrient phytochemical and phytochemical rich foods
- additional foods including sweeteners, vinegar, and alcohol
Carbohydrate

Typically provide the major energy contribution to our diet

Primary determinants of the glycaemic response

Reduce the size/duration of this in people with diabetes

Consider:
- Simple Sugars
- Oligosaccharides
- Polysaccharides (Dietary Fibre)
## Macronutrient Composition/Calorie Restriction?

Appropriate interventions required

- weight maintenance
- isocaloric
- long-term

<table>
<thead>
<tr>
<th>Diet Type</th>
<th>References</th>
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<tbody>
<tr>
<td>Low GI and Low GL Diets</td>
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<td></td>
<td>‘strong and significantly lower risk of T2DM with low GL diets’</td>
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<td>‘low carbohydrate, low GI, Mediterranean and high protein diet(s) deliver</td>
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<td>a greater improvement in glycaemic control’</td>
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Carbohydrate
Prospective studies:

• suggest that glucose and fructose have deleterious consequences
• no conclusive evidence for sucrose, maltose & lactose

Intervention studies:

• no short term deleterious effect of fructose
• increased postprandial glycaemia/insulinemia with sucrose

Raben et al Food & Nutr Research (2011); Anton et al Appetite (2010)

Studies with surrogate endpoints have shown detrimental effects of fructose on insulin resistance/sensitivity

Laville et al Obs Rev (2009)
High Intake of Dietary Fibre = Reduced Incidence of T2DM

Acute glycaemic/insulinaemic response effected by:

- type and amount of dietary fibre

- food matrix
Studies suggest that soluble fibre improves acute glucose/insulin response

These include: beta glucan, guar gum, psyllium, glucomannan

- Pastors (1991)

Viscosity is a major factor:

• absorbs water and reduces gastric emptying
• altered intestinal motility, slow diffusion rate
• reduced a-amylase accessibility and enzymatic digestion
Gut microbiota is recognised as a major contributor to human health

Preclinical studies suggest a role in regulation of glycaemia


Patients with diabetes have altered microbiota

## Prebiotics

Very few studies addressing the effect of prebiotics on PPG

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<th>Consumption of short chain fructans decreased basal hepatic glucose</th>
<th>Luo et al (1996)</th>
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<td>Inulin-type fructans increased GLP-1 and decreased PP glucose</td>
<td>Cani et al (2009)</td>
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</table>
No direct clinical evidence that probiotic bacteria effect PPG

Evidence of effect on related outcomes:
- Fasting glycaemia
- Insulin resistance

Reduced fasting glycaemia in elderly T2DM with FOS rich dairy product

*L. acidophilus, B. bifidum*

Moroti et al *Lipids Health Dis* (2012)

Reduced fasting glucose (but not HbA1c) in T2DM

*L. acidophilus (La-5), B. Lactis (Bb-12)*


Improvement in insulin sensitivity in non-T2DM and T2DM

*L. acidophilus (NCFM)*

High protein diets have a beneficial effect on weight loss, body composition and certain blood lipids and to increase insulin sensitivity

Nuttall et al, Diabetes Care (1984)

Amino acids stimulate insulin release
Leucine is particularly insulinotropic

Gunnerud et al; 2012

Reduction in PPG was observed following intake of whey and soy protein

Must consider protein/AA content in addition to glycaemic load
Dietary Fat

- Saturated fatty acids (SFA)
- Trans-unsaturated fatty acids (TFA)
- Monounsaturated fatty acids (MUFA)
- Polyunsaturated fatty acids (PUFA)

High Intake of Fat = Reduced Insulin Sensitivity

Lower Intake of Fat = Composition Dependant
Saturated Fatty Acids

Direct association with T2DM

Vessby et al Diabetologia (2001)

Mechanisms:

• impact on cell membrane composition/function

• intercellular enzyme activity and transcription

• exert damaging effects on β-cells

• ER stress

• inflammation
Nurses’ Health Study associated TFA with T2DB

Iowa Study showed no association

Postprandial Insulin levels higher compared to MUFA

Chrisiansen et al *Diabetes Care* (1997)

Lefevre et al *Metabolism* (2005)
No direct association with T2DB risk (Nurses’ Health Study)

Replacing SFA with MUFA improvement in insulin sensitivity

Potential Mechanism:

- incretin response/gastric emptying
- cytoprotection of β-cells
- improved β-cells function
- Increased glucose uptake (GLUT1/4)
  - Paniagua et al Diabetes Care (2007)
Polyunsaturated Fatty Acids

PUFAs (n-6; plant)
- improved insulin sensitivity
- reduced risk of T2DM

PUFAs (n-3; fish)
- inconstant results

Experimentally n-3 PUFA:
- anti-inflammatory activity
- increased leptin/adiponectin expression
- regulate genes involved in carbohydrate metabolism
Strong evidence associating vitamin D with T2DM

*Pittas et al; 2007 and Ozfirat et al 2010*

- meta analysis – low vitamin D status and T2DM
- interventions - beneficial effects of vitamin D repletion

**Mechanism:**
- β-cell function
- insulin resistance
- inflammation

Plasma levels of B vitamins reduced in some T2DM populations

*Page et al and Mitri et al; 2011*

No data supporting benefits of vitamins on postprandial glycaemia
Micronutrient Minerals

- **Cr** (24)
  - Important role in glucose homeostasis
  - Supplementation beneficial in T2DM
  - Reduction in fasting and postprandial glucose

- **Mg** (12)
  - Involved in glucose transport and metabolism
  - Reduced Mg levels in T2DM
  - Lack of data regarding postprandial glycaemia
  - Sales et al (2011)

- **Zn** (30)
  - Important role in insulin synthesis
  - Plasma/Tissue concentrations low in T2DM
  - Reduction in fasting and postprandial glucose
  - Gunasekara et al (2011)
Most widely studied phytochemicals are phenylpropanoid-derived

- flavanoids
- phenolic acids

Human Intervention Studies (acute effect on PPG)

- chocolate
- grape seed, fig, mixed berries
- nuts (almonds, pistachio, mixed)
- tea, coffee
- cinnamon, ginseng, salacia
- seaweed, fraxinius

Non-Nutrient Phytochemicals

Action unknown - poor classification/metabolism/bioavailability

Potential Mechanisms:

- inhibition carbohydrate digestion
- modulation of glucose release
- stimulation of insulin secretion
- delayed gastric emptying
- inhibition of lipolysis
- decrease in oxidative stress
- inhibition of inflammation
J-shaped association with T2DM

Moderate consumption improved insulin sensitivity

Potential Mechanisms:

• acetate, reduces fatty acid release
• inhibits uptake of circulating fatty acid by muscle
• enhance glucose oxidation and insulin sensitivity

Addition of water to a test meal increased glucose response in:

• healthy individuals
• well controlled T2DM

No significant effect in poorly controlled T2DM

Torsdottir and Andersson *Diabetologia* (1989)
Low-Calorie Sweeteners

Could be useful to address the obesity epidemic

- beneficial effect on energy intake
- decreased body weight and liver fat

*Raben and Richelsen; 2012*

Could impact on the risk for diabetes and CVD

- some evidence form large cohort studies

*De Koning et al; 2012*

Evidence for blood glucose regulation?
Low-Calorie Sweeteners

**Aspartame, Acesulfame-K, Cyclamate, Saccharin**
- no increase in blood glucose/insulin (moderate dose; acute)
  
  Härtel et al (1993)

**Sucralose, Stevioside**
- no effect on blood glucose levels (T2DM; high dose; acute)
  
  Mezitis et al (1996)
- no effect of fasting plasma glucose HbA1c (T2DM; high dose; chronic)
  
- postprandial glycaemia significantly lowered (T2DM; lean and obese, preloads)
  
  Anton et al (2010)

**Sweeteners vs. Sucrose**
- postprandial glycaemia, insulinemia and lipidemia (healthy overweight; chronic)
  
  Raben et al; 2011)
Summary

**Dietary Factors with potential to impact on blood glucose**

- **Macronutrients**
  - carbohydrate
  - protein
  - fat

- **Micronutrients**
  - vitamins
  - minerals

- **Non-nutrients**
  - phytochemicals

- **Other Sources**
  - alcohol
  - water
  - vinegar
  - sweeteners

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**NORMAL GLUCOSE TOLERANCE**

- β-cell hypertrophy

**PREDIABETES**

- β-cell mass instability
- reduction in blood glucose

**TYPE 2 DIABETES MELLITUS**

- β-cell mass reduction
- β-cell mass severe reduction

**β-cell dysfunction/decreasing β-cell mass**

- loss of acute GSIS
- impaired insulin resistance
- changes in gene/protein expression
- up-regulation of inflammatory markers
Strongest corroboration of efficacy:
• insoluble and moderately fermentable cereal-based fibre
• mono-unsaturated fatty acids as replacement of saturated fat

Postprandial glycaemia was decreased by intake of viscous soluble fibre

Weaker but substantial evidence that phytochemical-rich foods were likely to be effective.

Gut microbiota plays an important role in metabolic regulation (includes provision of phytochemical and other metabolites)

Need:
• more well-planned studies are required
• better characterisation of potential bio-actives
• magnitude of effect between dietary groups
• correlation of acute effects with long-term outcomes
Conclusions

Dietary components have significant and clinically relevant effects on blood glucose modulation.

Should employ a dietary regimen to attenuate the postprandial rise in blood glucose levels along with previously identified targets (reducing excess body weight and an increase in physical activity).

An emphasis of dietary prevention will benefit the health of the population and limit the increasing worldwide incidence of T2DM.

Impact of diet composition on blood glucose regulation

*Critical Reviews in Food Science and Nutrition 2013*

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