The Diabetic Athlete

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Goals & Objectives

• Discuss basic understanding of glucose & insulin
• Discuss implications for our athletes
• Recognizing and treating emergencies
• Discuss cases
Diabetes Bottom Line

- Relative or absolute *insulin deficiency*
TYPE 2 DIABETES: LITTLE OR NO REACTION TO INSULIN
Glucose Metabolism

**Figure 1.** Insulin inhibits glucose release from the liver and FFA release from adipose tissue, and stimulates glucose uptake into muscle. Counter-regulatory hormones, CGC, oppose insulin’s action at the liver and adipose tissue. Acetyl Co-A—acetyl coenzyme A; CGC—catecholamine, glucagon, cortisol; G-6-P—glucose 6 phosphate; FFA—free fatty acid; Lac—lactate; Pyr—pyruvate. (Adapted from Hough [2].)
Exercise & Muscle

Figure 1  Glucose uptake in skeletal muscle. Insulin and exercise independently facilitate glucose transport across the mitochondrial membrane through promotion of GLUT4 transporters from the vesicles. The action is also cumulative producing enhanced glucose uptake/sensitivity during and after exercise. IRS-1, insulin receptor substrate 1; PI 3-kinase, phosphatidylinositol 3-kinase. Modified from Goodyear.147

Exercise & Muscle

Paracrine effect?

Insulin

Insulin receptor

IRS-1

PI 3-kinase

Ca$^{2+}$

Sarcoplasmic reticulum

Glucose

GLUT4 receptors

Glucose

Vesicle of GLUT4 receptors

Figure 1  Glucose uptake in skeletal muscle. Insulin and exercise independently facilitate glucose transport across the mitochondrial membrane through promotion of GLUT4 transporters from the vesicles. The action is also cumulative producing enhanced glucose uptake/sensitivity during and after exercise. IRS-1, insulin receptor substrate 1; PI 3-kinase, phosphatidylinositol 3-kinase. Modified from Goodyear.}\h

What happens during Exercise?

- Brief bouts of exercise
  - Source of Energy
    - Muscle ATP
    - Muscle phosphocreatine
  - Replenished by muscle glycogen
  - 2-30 seconds
After 30 seconds...

- Source of energy
  - Liver gluconeogenesis from muscle lactate
  - Adipose tissue free fatty acids (FFA)
After 1 hour...

- Source of energy
  - FFAs
- Aerobic training
  - Adaptation to preferentially use FFAs rather than glycogen stores
  - Reduces muscle glycogen depletion
Isn’t this a Diabetes Workshop?
Too much insulin

- ↓ Production of liver glucose
- ↑ Uptake of available glucose by muscle

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Not enough insulin

- ↓ Glucose uptake
- ↑ Liver glucose production
- ↑ Lipolysis
- ↑ Ketogenesis

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Postexercise hyperglycemia

- Very dangerous situation
  - Hyperglycemia
  - Hyperlipidemia
  - Ketoacidosis
  - Coma
Hyperglycemia

Hypoglycemia
Hyperglycemia & Hypoglycemia
Diabetes
Laboratory Diagnosis

- Fasting Glucose $\geq 126$ mg/dL
- Random Glucose $\geq 200$ mg/dL
- 2 hr Oral Glucose Tolerance Test (OGTT)
  - $\geq 200$ mg/dL
- Confirmation with repeat testing is generally required.
Pre-Diabetes

- Impaired Fasting Glucose (IFG)
  - Fasting glucose: 100-125 mg/dL

- Impaired Glucose Tolerance (IGT)
  - 2 hr OGTT: 140-199 mg/dL
Symptoms

- Type I Diabetes
  - Increased thirst
  - Increased urination
  - Hunger
  - Fatigue
  - Wt. loss

- Type II Diabetes
  - Increased thirst
  - Increased urination
  - Hunger
  - Fatigue
Goals of Treatment

- Minimize complications of diabetes
- Tight glucose control
- BP control
- Cholesterol
- Monitor Kidney Function
- Reduce retinal complications
- Reduce neuropathy
Tight Glycemic Control

• Better control reduces complications
Tight Glycemic Control

Cumulative Incidence of a Sustained Change in Retinopathy in Patients with IDDM Receiving Intensive or Conventional Therapy

Tight Glycemic Control

Cumulative Incidence of Urinary Albumin Excretion $\geq 300$ mg per 24 Hours (Dashed Line) and $\geq 40$ mg per 24 Hours (Solid Line) in Patients with IDDM Receiving Intensive or Conventional Therapy

Tight Glycemic Control

Prevalence of Abnormal Clinical Neurologic Examinations, Abnormal Results of Nerve-Conduction Studies, and Abnormal Autonomic-Nerve Studies at Five Years in Patients Receiving Intensive (Solid Bars) or Conventional (Hatched Bars) Therapy

Tight Glycemic Control

- Glycohemoglobin (HgbA1c)
- Average BS over the last 3 months
Tight Glycemic Control
• ADA
  • < 7.0

• ACE
  • < 6.5
HgbA1c

- ADA
  - < 7.0
- ACE
  - < 6.5

The lower, the better.
<table>
<thead>
<tr>
<th></th>
<th>ADA</th>
<th>AACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasting glucose</td>
<td>90-130</td>
<td>&lt;110</td>
</tr>
<tr>
<td>After meals</td>
<td>&lt;180</td>
<td>&lt;140</td>
</tr>
</tbody>
</table>
Blood pressure

- $< 130/80$
Blood pressure

• $< 130/80$

The lower, the better.
Cholesterol

- Diabetes is a coronary heart disease (CHD) equivalent.
  - LDL < 100
Cholesterol

- Diabetes is a coronary heart disease (CHD) equivalent.

- LDL < 100

The lower, the better.
Kidney Function

• The first sign of kidney damage is protein in the urine.

• ACE inhibitors may be prescribed to decrease proteinuria.
Kidney Function

- The first sign of kidney damage is protein in the urine.

- ACE inhibitors may be prescribed to decrease proteinuria.

The less protein, the better.
Eye complications

• Diabetic retinopathy

• Yearly dilated retinal examination
### Eye complications

**Table 4 Exercise guidelines in retinopathy**

<table>
<thead>
<tr>
<th>Level of diabetic retinopathy</th>
<th>Acceptable activities</th>
<th>Discouraged activities</th>
<th>Ocular re-evaluation (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>*</td>
<td>*</td>
<td>12</td>
</tr>
<tr>
<td>Non-proliferative</td>
<td>*</td>
<td>*</td>
<td>6–12</td>
</tr>
<tr>
<td>Mild</td>
<td>*</td>
<td></td>
<td>4–6</td>
</tr>
<tr>
<td>Moderate</td>
<td>*</td>
<td>Dramatic increase in BP e.g. weights, valsalva</td>
<td>2–4</td>
</tr>
<tr>
<td>Severe</td>
<td>*</td>
<td>Substantial inc. BP e.g. boxing, rowing. High impact, anaerobic, aerobic, racquet</td>
<td>1–2</td>
</tr>
<tr>
<td>Proliferative</td>
<td>Low impact, aerobic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Dictated by medical status. Modified from ACSM/ADA guidelines.*

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This table provides guidelines for exercise based on the level of diabetic retinopathy. The table lists the level of retinopathy (None, Non-proliferative, Mild, Moderate, Severe, Proliferative), acceptable activities, discouraged activities, and the recommended ocular re-evaluation period in months. The activities are marked with an asterisk (*). The discouraged activities include dramatic increase in blood pressure (BP) and high-impact activities. The re-evaluation periods vary from 1 to 12 months, depending on the severity of the retinopathy.
Diabetic neuropathy

Monofilament testing
Diabetic neuropathy

- Sensory neuropathy
- Autonomic neuropathy
  - Orthostatic hypotension
  - Maximal heart rate
  - Gastric emptying
<table>
<thead>
<tr>
<th>Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular</td>
</tr>
<tr>
<td>Hypotension during and after exercise (esp. vigorous activity)</td>
</tr>
<tr>
<td>Hypertension during exercise</td>
</tr>
<tr>
<td>Orthostatic hypotension (may be worse in the morning)</td>
</tr>
<tr>
<td>Cardiac denervation syndrome</td>
</tr>
<tr>
<td>reduced maximal heart rate</td>
</tr>
<tr>
<td>raised resting heart rate</td>
</tr>
<tr>
<td>Silent ischaemia</td>
</tr>
<tr>
<td>Impaired thermoregulation in hot and cold climate</td>
</tr>
<tr>
<td>Altered sweating</td>
</tr>
<tr>
<td>Altered cutaneous blood flow</td>
</tr>
<tr>
<td>Impaired proprioception (increased injury potential)</td>
</tr>
<tr>
<td>Impaired respiratory reflexes</td>
</tr>
<tr>
<td>Delayed gastric emptying</td>
</tr>
<tr>
<td>Diarrhoea</td>
</tr>
<tr>
<td>Impaired perception of hypoglycaemia</td>
</tr>
<tr>
<td>Pupillary</td>
</tr>
</tbody>
</table>
### Table 1. Preparticipation evaluation of the athlete with type 1 diabetes

<table>
<thead>
<tr>
<th>Has a routine of stable blood glucose control been established?</th>
<th>1. Recent satisfactory measurement of glycosylated hemoglobin levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Habitual (2–3 times/day) self-monitoring of blood glucose levels</td>
</tr>
<tr>
<td></td>
<td>3. Understanding of indications for, or interpretations of, urine ketone measurement</td>
</tr>
<tr>
<td>Has the possibility of hypoglycemia been anticipated?</td>
<td>1. Recognition of early warning signs of hypoglycemia</td>
</tr>
<tr>
<td>Requirements for the athlete:</td>
<td>2. Knowledge of treatment strategies for mild hypoglycemia (eg, hard candy, glucose tablets)</td>
</tr>
<tr>
<td></td>
<td>3. Knowledge of strategies to be followed in case of pre-exercise and postexercise alterations in insulin dosage</td>
</tr>
<tr>
<td></td>
<td>4. Medic-alert bracelet or necklace indicating diabetic state</td>
</tr>
<tr>
<td></td>
<td>5. Provision of glucagon (1 mg for subcutaneous or intramuscular injection by trained personnel) for treatment of severe hypoglycemia</td>
</tr>
<tr>
<td>Are complications of diabetes present?</td>
<td>1. Recent evaluation of blood pressure, neurologic function, joint mobility, and skin condition</td>
</tr>
<tr>
<td></td>
<td>2. Recent retinal examination by licensed ophthalmologist</td>
</tr>
<tr>
<td></td>
<td>3. Screening laboratory evaluation for blood lipid abnormalities and diabetic nephropathy</td>
</tr>
</tbody>
</table>

(Data from Landry and Allen [15].)
PPE red flags

- HgbA1c > 9 (avg BS= 240)
  - Risk for hyperglycemia/DKA
- Neuropathy
  - Risk for foot injuries
  - Risk for autonomic neuropathy
- Retinopathy
  - Risk of hemorrhages
Management

- Diet/exercise
- Oral Medications (Type 1 I Diabetes)
- Injectable insulin
Oral medications

- Sulfonylureas
- Metformin
- Thiazolidinediones (TZD)
- \(\alpha\)-Glucosidase inhibitors
- Glimeparides
- Byetta
Oral medications

- Sulfonylureas
- Metformin
- Thiazolidinediones (TZD)
- $\alpha$-Glucosidase inhibitors
- Glimeparides
- Byetta
Insulin

- Type 1
  - Insulin

- Type 11
  - +/- Medications
  - +/- Insulin
Rapid (Lispro, Glulisine, Aspart)

Insulin Effect

Rapid (Lispro, Glulisine, Aspart)

Short (Regular)

Intermediate (NPH)

Figure 1. Profile of ideal insulin replacement pattern.
Basal-Bolus Therapy Using Split-Mixed Regimen and Bedtime Intermediate Insulin

Figure 6. Split-mixed regimen. (Neutral protamine Hagedorn = NPH)
Figure 6. Split-mixed regimen. (Neutral protamine Hagedorn = NPH)
Split-Mixed

- Intermediate acting + Short acting
- Pre-mixed
  - 70/30
  - 75/25
  - 50/50
- Limits your flexibility
Basal-Bolus Therapy Using Glargine and Aspart or Lispro

Plasma Insulin (µU/mL)

Breakfast  | Lunch  | Dinner
---        | ---    | ---
Aspart or lispro  | Aspart or lispro  | Aspart or lispro

Time:
4:00  | 8:00  | 12:00  | 16:00  | 20:00  | 24:00  | 4:00

Glargine

Basal-Bolus

• Long-acting at night
• Very, very short acting prior to meals
  • Lantus at night
  • Humalog before meals
Where do insulin doses come from?

- YMMV principle
- Individualize regimen
  - Age
  - Sensitivity to insulin
  - Physical activity
Total Daily Dose (TDD)

- 0.5 - 1.0 Units/kg/Day

- Example
  - 70 kg
  - 35 - 70 Units per day
Insulin-to-Carbohydrate Ratio

The amount of rapid/short acting insulin required to cover a specific number of grams of carbohydrate is called the *insulin-to-carbohydrate ratio*. This ratio helps you calculate how much insulin you need for the amount of carbohydrate you plan to eat. Each person has his or her own insulin-to-carbohydrate ratio. This ratio may vary for different times of the day. An easy way to begin using an insulin-to-carbohydrate ratio is to use The Rule of 500. This method is based on your Total Daily Dose (TDD) of insulin divided into 500.

It is recommended that you determine your insulin-to-carbohydrate ratio when your blood glucose levels are within your target.

The Rule of 500

\[ \frac{500}{\text{TDD}} = \text{Insulin-to-carbohydrate ratio} \]
Example:
TDD is 36 units (Your TDD of insulin includes all insulin, both basal and bolus)
$500 \div 36 = 13.8$ (round to 14)
Insulin-to-carbohydrate ratio would be 1 unit for every 14 g carbohydrate
Example:

Insulin-to-carbohydrate ratio of 1 unit of insulin (rapid/short acting) for every 14 grams of carbohydrate

<table>
<thead>
<tr>
<th></th>
<th>Grams of Carbohydrate</th>
<th>Units of Insulin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cup cooked cereal</td>
<td>30</td>
<td>2.1</td>
</tr>
<tr>
<td>1 cup (1%) milk</td>
<td>12</td>
<td>0.9</td>
</tr>
<tr>
<td>1 small banana</td>
<td>20</td>
<td>1.4</td>
</tr>
<tr>
<td>Black coffee with</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>non-nutritive sweetener</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>62 grams</strong></td>
<td><strong>4.4 units</strong></td>
</tr>
</tbody>
</table>

*How much insulin? 62 ÷ 14 grams = 4.4 units*
Insulin Pump

• Continuous subcutaneous insulin infusion (CSII)
• Short acting and basal insulin delivered via catheter inserted into skin
• More flexibility
  • Skipped meals
  • Sleeping late
• Spontaneous exercise
Basic Tenets of Management

- Prevent Hypoglycemia
- Prevent Hyperglycemia
Basic Tenets of Management

- Prevent Hypoglycemia
- Prevent Hyperglycemia

Manage Hypoglycemia
Manage Hyperglycemia
Glucose Control: The Basics

- Start with adequate glucose control
- Eat 1-3 hours before exercise
- Adjust insulin dose
- Adjust carbohydrate intake
- Exercise after peak action of insulin
Case 1

- 17 y/o female soccer athlete
- Type 1 DM since age 8
- Excellent control prior to the season
- Comes off the field feeling “dizzy”
Data gathering

Emergency

Not an emergency
Emergency

- Altered Consciousness
- Confused
- Combative
- Unconscious
- Seizures
- Death
Emergency Management

- 911
- Administer glucagon
  - Won’t work in carbohydrate depletion
- Do not give anything orally
  - Not even glucose gel on the gums
- What happens if the athlete is a minor?
Non-emergent management

- Symptoms of hypoglycemia
  - “Dizzy”
  - Shaky
  - Sweating
  - Hunger
  - Moodiness
  - Clumsiness
Non-emergent management

"I just feel a little shaky."
Blood Glucose

BS = 50
Non-emergent

• Administer simple carbohydrate (15-30 g)
• Glucose tabs (15 g/tablet)
• Fruit juice (OJ= 25 g/8 oz.)
• Sports drink
• 1/2 can of soda (39 g/can)
• Packets of table sugar (10-15 g/packet)
• Recheck BS every 15-20 minutes
Case 2

- 20 y/o collegiate football player
- Presents for PPE
- Hasn’t seen his endocrinologist over the summer
- A1c?
Case 2

- 20 y/o collegiate football player
- Presents for PPE
- Hasn’t seen his endocrinologist over the summer
- A1c?

“Last I checked, I think it was around 10?”
Labs

- Blurry vision
  - "I’m peeing all the time"

- Random BS= 325

- Urinalysis reveals 2+ ketones

- A1c= 11.4
Management

- Exclude from play?
- If so, for how long?
No right answers

• Well-accepted Criteria

• No exercise if:
  • BS > 250 and ketones in the urine
  • BS > 300 +/- ketones
Ketones

- Indicate lack of insulin
- Body utilizing FFA’s as main source of fuel
- Exercise in this state can cause glucose levels to rise to dangerous levels.
  - Can lead to DKA
Management

- Withhold from play
- Review medication regimen
- Get the patient to a Team Physician
- Modify insulin regimen
- Frequent monitoring
- RTP typically quick in this situation
Case 3

- 18 y/o long-distance runner
- Easy case
  - 5 miles per day at 2:00 PM every day for 2 hrs
- Regimen
  - Lantus 20 units at night
  - Lispro ~10 units pre-meals
Data

- **A1c** = 6.5
- No ketones in urine
Adjustments

- Eat 1-3 hrs before exercise
  - Lunch at noon
- Adjust Insulin dose
  - ??
- Adjust carbohydrate intake
  - ??
- Avoid exercise at peak onset of insulin
Basal-Bolus Therapy Using Glargine and Aspart or Lispro

Plasma Insulin (µU/mL)

Breakfast  Lunch  Dinner
Aspart or lispro  Aspart or lispro  Aspart or lispro

Time
4:00  8:00  12:00  16:00  20:00  24:00  4:00

Glargine
Basal-Bolus Therapy Using Glargine and Aspart or Lispro

Plasma Insulin (µU/mL)

4:00 8:00 12:00 16:00 20:00 24:00 4:00

Time

Aspart or lispro

Aspart or lispro

Aspart or lispro

Glargine
<table>
<thead>
<tr>
<th>Intensity</th>
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<th>20–60 min</th>
<th>&gt; 60 min</th>
<th>&gt; 60 min (insulin dosage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 60%</td>
<td>0 g</td>
<td>15 g</td>
<td>30 g/h</td>
<td>-20%</td>
</tr>
<tr>
<td>60%–75%</td>
<td>15 g</td>
<td>30 g</td>
<td>75 g/h</td>
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<tr>
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<td>100 g/h</td>
<td>-30%</td>
</tr>
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(Data from Grimm et al. [7**].)

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</tr>
</tbody>
</table>

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**Table 2. Extra carbohydrate and insulin adjustment for different physical activity depending on duration and intensity (percentage of maximal heart rate)**

<table>
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<tr>
<th>Intensity</th>
<th>&lt; 20 min</th>
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<th>&gt; 60 min</th>
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(Data from Grimm et al. [7**].)

Decrease lunch Lispro by 20%

10 units × 0.2 = 2 units

10 units - 2 units = 8 units

+ Carbohydrate @ 75 g/hr
No one is ever that easy!

• Backup vs. everyday player
• Overtime
• Rain delay
• Bus breaks down on the way to match
Case 4

- 17 y/o football player uses insulin pump
An insulin pump can be worn discretely under clothing as it administers insulin to the diabetic.
Having diabetes is certainly not fun, and probably is pretty inconvenient. You've got to remember to bring all your supplies, be it a glucometer, insulin, and anything else you need to keep healthy everywhere you go. That can't be fun.

The folks over at Cambridge Consultants realize that and want to make it a bit less inconvenient. Recently they announced a device that integrates close-proximity wireless with an insulin pump and a glucometer.

The device utilizes the close-proximity wireless standard, NFC, to wirelessly link the insulin pump and glucometer. Your glucometer will record your blood sugar level then recommend a dose of insulin. If you accept the dose, all you need to do is swipe the glucometer against the insulin pump, which can be hidden under your clothes, and it will issue the dosage.

There's also a feature that Cambridge Consultants call "patient-in-the-loop dosing", which gives a confirmation message to the patient when the dosage is administered and allows the patient to...
Insulin pump

- Typically the most motivated patients
- Typically well-controlled
- Allow them to teach you about diabetes
Insulin pump

- Basal rate
- Pre-meal bolus
- Rapid-acting insulin only
Basal rate

- Intense activity
  - Reduce basal rate by 50% 1 hr prior to exercise
- Shorter, less intense activity
  - Reduce pre-meal insulin
Pitfalls

- Sweating
- Malfunctioning of pump
- Insulin is heat sensitive
- Contact sports
Contact sports

• Remove pump
  • 30 minutes prior to short bouts of exercise (< 1 hr)
  • Longer exercise (> 1 hr) may require insulin administration during activity
    • Given every hr @ 50% usual hourly rate
Role of the ATC

- Care of the catheter site
- Monitor for signs of hypo- and hyperglycemia
Case 5

- 22 y/o collegiate softball pitcher
- Won title game 3-2 in 17 innings (4 hrs)
  - Pitched for 15 of those innings
- BS “OK” all game
- Knocks on your hotel room door at 2:00 AM feeling “funny”
Data

• Just awoke from horrible nightmare
• Hungry & sweating
• Pale
• Irritable
Data

• Previously well-controlled (A1c= 7.0)
• Insulin regimen
  • Insulin 70/30
    • 25 Units in the morning
    • 10 Units at night
    • Decreased AM dose to 15 units
Data

- Previously well-controlled (A1c= 7.0)
- Insulin regimen
  - Insulin 70/30
    - 25 Units in the morning
    - 10 Units at night
    - Decreased AM dose to 15 units

“How was I supposed to know the game would go that long?”
Blood Sugar?
Blood Sugar?

45
Postexercise hypoglycemia

- 6-24 hrs after exercise (nocturnal)
- Muscle and liver glycogen levels are restored
- Muscle has increased insulin sensitivity
- Assoc. with increased exercise intensity
Management

- Same as in-activity hypoglycemia
- Remember emergency vs. non-emergency
- Monitor closely every 15-20 minutes until normal
Management

• Same as in-activity hypoglycemia

• Remember emergency vs. non-emergency

• Monitor closely every 15-20 minutes until normal

Order a carafe of coffee for the morning.
Summary

- Individualize treatment
- Prevention of hypo- and/or hyperglycemia is a better strategy than management
  - Be prepared to manage emergencies
- Allow your diabetic athletes to teach you about diabetes