The Young Diabetic Athlete

Vincent Disabella DO FAOASM
Immediate Past President
AOASM

Goals and Objectives

- Diabetes Review
- Insulin and Exercise
- Type 2 Diabetes Mellitus
- Type 1 Diabetes Mellitus
- Diet

Objectives

- To review and compare exercise metabolism in euglycemic and diabetic patients.
- To provide guidance for counseling and management of diabetics in pursuit of exercise.

TYPE 1 DIABETES MELLITUS

- [a.k.a. Type I DM, IDDM, Juvenile-Onset DM]
- Deficiency of insulin
- Prone to ketoacidosis
- ß-cell destruction.
- Immune mediated.
- Idiopathic (no evidence of autoimmune etiology)

TYPE 2 DIABETES MELLITUS

- [aka Type II DM, NIDDM, Adult-Onset DM]
  - State of insulin resistance with relative insulin deficiency.
  - Predominant deficiency of insulin with resistance to insulin action.

DIAGNOSTIC CRITERIA FOR DIABETES MELLITUS

Either:

1. Sx of diabetes plus
   random plasma glucose $\geq$ 200 mg/dl
   (11.1 mmol/l)

2. Fasting Plasma Glucose $\geq$ 126 mg/dl
   (7.0 mmol/l)

3. OGTT: 2 hr postload glucose $\geq$ 200 mg/dl
   (11.1 mmol/dl)

ENERGY FUELS FOR EXERCISE

GLUCOSE (Intestinal Absorption, Blood Stream, Liver and Muscle)
- The basic carbohydrate for energy production
- Readily transferred between bloodstream and liver or muscle

GLYCOGEN (Muscle and Liver)
- Storage form of carbohydrate (glucose) in muscle and liver
- Fuel source that is readily mobilized providing glucose

TRIGLYCERIDES (Adipose Tissue and Muscle)
- High yield-slow release form of energy storage
- Provides twice the energy per gram than carbohydrate
- LYPOLYSIS yields **free fatty acids** and **glycerol**

PROTEIN (Liver)
- Minimal energy contribution (~10%) through gluconeogensis

HORMONAL REGULATION OF ENERGY METABOLISM

- Insulin: Lowers Blood Glucose
- Glucagon: Raises Blood Glucose
- Catecholamines: Raises Blood Glucose
- Cortisol: Raises Blood Glucose
- Growth Hormone: Raises Blood Glucose

PHYSIOLOGIC EFFECTS OF EXERCISE IN NON-DIABETICS VS DIABETICS

HORMONAL CHANGES WITH EXERCISE IN NON-DIABETICS

- INSULIN levels decline
- GLUCAGON rises
- CATECHOLAMINES rise.

Glycogen stores progressively become depleted.
Later glucose availability is from gluconeogensis or ingested glucose.

PHYSIOLOGIC EFFECTS OF EXERCISE IN NON-DIABETICS VS DIABETICS

HORMONAL CHANGES WITH EXERCISE IN DIABETICS

INSULIN

Normal **physiologic decline** in insulin with exercise **absent**

Accelerated absorption from injection site
➡ levels above non-exercising baseline

Much **individual variation** re: injection site absorption patterns

Insulin sensitivity in Type 2 DM **enhanced** with exercise
just 3-4 days/week

PHYSIOLOGIC EFFECTS OF EXERCISE IN NON-DIABETICS VS DIABETICS

HORMONAL CHANGES WITH EXERCISE IN DIABETICS

CATECHOLAMINES

Release may be abnormal due to autonomic dysfunction.

GLUCAGON

Deficiency is common in diabetics.

PHYSIOLOGIC EFFECTS OF EXERCISE IN NON-DIABETICS VS DIABETICS

GLUCOSE METABOLISM IN EXERCISE

Energy expenditure for exercise centers around mobilization and metabolism of glucose for early energy expenditure subsequently augmented by breakdown of triglycerides yielding (free fatty acids and glycerol) for prolonged energy expenditure.

Glucose homeostasis depends on the coordination between glucose intake, storage and utilization directed by an intricate balance between insulin and the counter-regulatory hormones activity.

PHYSIOLOGIC EFFECTS OF EXERCISE IN NON-DIABETICS VS DIABETICS

EXERCISE AND GLUCOSE METABOLISM IN NON-DIABETICS

- Slight ↓ blood glucose initially then stabilizes
  - counter-regulatory hormones
  - glycogen stores
  - carbohydrate intake during exercise

- Skeletal muscle glucose uptake ↑
  - enhanced responsiveness to insulin
  - activation of direct myocyte uptake (independent of insulin)

- Baseline serum glucose ↓ in the long term
  - ↑ efficiency of glucose transport, storage and mobilization

PHYSIOLOGIC EFFECTS OF EXERCISE IN NON-DIABETICS VS DIABETICS

EXERCISE AND GLUCOSE METABOLISM IN EXERCISE IN DIABETICS

Trends not as predictable (interplay of multiple factors)

Injected insulin cannot mimic the physiologic patterns

↑ glucose uptake and utilization
↓ serum glucose in both Type 1 and Type 2

↑ response to insulin
decreased glucose for given dose of insulin

PHYSIOLOGIC EFFECTS OF EXERCISE IN NON-DIABETICS VS DIABETICS

EXERCISE AND GLUCOSE METABOLISM IN EXERCISE IN DIABETICS

Caveats:

Ketosis prone diabetics tend to have elevation of serum glucose

Diabetic children prone to greater variability in blood glucose response

FACTORS AFFECTING EXERCISE GLUCOSE METABOLISM IN DIABETICS

PHYSIOLOGIC FACTORS	PHARMACOLOCIC FACTORS
Status of Metabolic Control	Type of Insulin / Oral Hypoglycemic Agent
Fitness Level	Site of Insulin Injection
Blood Glucose at Onset of Exercise	Time of Insulin Injection
Insulin Resistance	

FACTORS AFFECTING EXERCISE GLUCOSE METABOLISM IN DIABETICS

EXERCISE FACTORS

- Timing of Exercise
- Intensity of Exercise
- Duration of Exercise
- Type of Exercise
- Frequency of Exercise

CALORIC INTAKE

- Timing of Pre-Exercise Meal
- Caloric Content of Pre-Exercise Meal (Quantity and Type)

PHYSIOLOGIC EFFECTS OF EXERCISE IN NON-DIABETICS VS DIABETICS

LIPID METABOLISM AND EXERCISE

NON-DIABETIC	DIABETIC
↑ HDL Cholesterol	↑ HDL Cholesterol
↓ LDL Cholesterol	↓ LDL Cholesterol (variable)
↓ Total Cholesterol	↓ Total Cholesterol
↓ VLDL	↓ VLDL

- Exercise in diabetics has same beneficial effects on lipids as non-diabetics, though greatest achievable gains are in Type 2 DM

- These effects often attenuated in diabetes and degree of improvement somewhat correlates with adequacy of glycemic control.

GUIDELINES FOR EXERCISE IN DIABETES

GENERAL RECOMMENDATIONS

- Most of the general principles for exercise in non-diabetics are applicable to diabetics

- Attention to carbohydrate intake and utilization must be more vigilant in the diabetic

- Prescreening for comorbid conditions frequently associated with DM

EXERCISE ACTIVITIES

- Maintain a standardized exercise regimen avoiding major variance
- Self blood glucose monitoring before, during and after exercise is paramount.
- Attention to caloric intake before during and after exercise, especially events >1hr
- Attention to hydration before during and after exercise, especially events >1hr
- Avoid exercising at extremes of temperature when autonomic neuropathy present
- Avoid exercising when sick.
- Warm Up (5-10 min low intensity aerobic) and Cool Down (5-10 min)
- Exercise at Moderate Intensity
  - (☒ 50-70% MVO_2 or PMHR, or RPE = 12-13)

NUTRIENT INTAKE

Eat a meal 1-3 hours before exercise

Carbohydrate snack 15-30 minutes before exercise protects against post-exercise hypoglycemia

Carbohydrate for Replacement of Glycogen Stores

- ➡ Meals: 60% Carbohydrate
- ➡ Exercise $\leq$ 1 Hr/Day - 5-6 g/kg/day
- ➡ Exercise > 2 Hr/Day - 8 g/kg/day
- ➡ Coordinate Insulin dose/activity with food intake

Ingest supplemental carbohydrate during exercise for exercise > 1 hr

- ➡ 15-30 g/hr divided every 15-30 minutes

NUTRIENT INTAKE

Fluid Intake

Need correlates to losses - depends on factors of heat, humidity, sweat rate and duration of exertion

Thirst is poor indicator of fluid need during exercise

- ➡ Weight loss most accurate: 1 lb. wt loss ≅ 15 oz (450 cc) water [add to fluid consumed]
- ➡ General guide: 8 oz (240 cc) every 20 minutes

Ingestion of Carbohydrate drink of 6-8% CHO during exercise typically meets fluid and carbohydrate intake need

SPECIAL CONSIDERATIONS

INSULIN ABSORPTION

Absorption rates from different injection sites not consistently predictable between different individuals

Absorption from ABDOMEN is FASTER AT REST than from extremities

Absorption from ABDOMEN is MORE CONSISTANT than from extremities

Absorption is accelerated when injected into area of exertion

Delaying exercise 30 minutes after injection of Lispro allows better glycemic control for exercise period

ORAL HYPOGLCEMIC AGENTS

Potential to cause hypoglycemia may be potentiated for several agents, though risk typically less than for patients who require insulin.

Sulfonylureas : most commonly associated with hypoglycemia

metformin : avoid dehydration
: potential for lactic acidosis

HYPOGLYCEMIA

May arise from one or more of:

- ➡ Excess exogenous insulin
- ➡ Inadequate calorie intake
- ➡ Exercise / Caloric Expenditure greater than anticipated
- ➡ Typically occurs *after* exercise, Late Onset Hypoglycemia more common

Due to dangers of hypoglycemic state **SCUBA Diving, Rock Climbing, and Long Distance Swimming are contraindicated in diabetics**

Late Onset Hypoglycemia

May occur 6 to 28 hours after strenuous exercise

May be more of a problem for some diabetics than hypoglycemia during exercise.

Typically nocturnal; often severe with seizures or coma.

Due to:

- ➡ Depletion of glycogen stores.
- ➡ Inadequate replenishment of glycogen stores post exercise.
- ➡ Increased sensitivity to insulin post exercise.
- ➡ Increased glucose uptake and glycogen synthesis in depleted muscle groups.

Most commonly associated with prolonged strenuous exertion in individuals unaccustomed to such or after periods of prolonged inactivity.

Late afternoon/early evening exercise higher risk

HYPERGLYCEMIA POST EXERCISE

Insulin deficiency

- ➡ Decreased cellular uptake of glucose
- ➡ Increase in liver glucose production

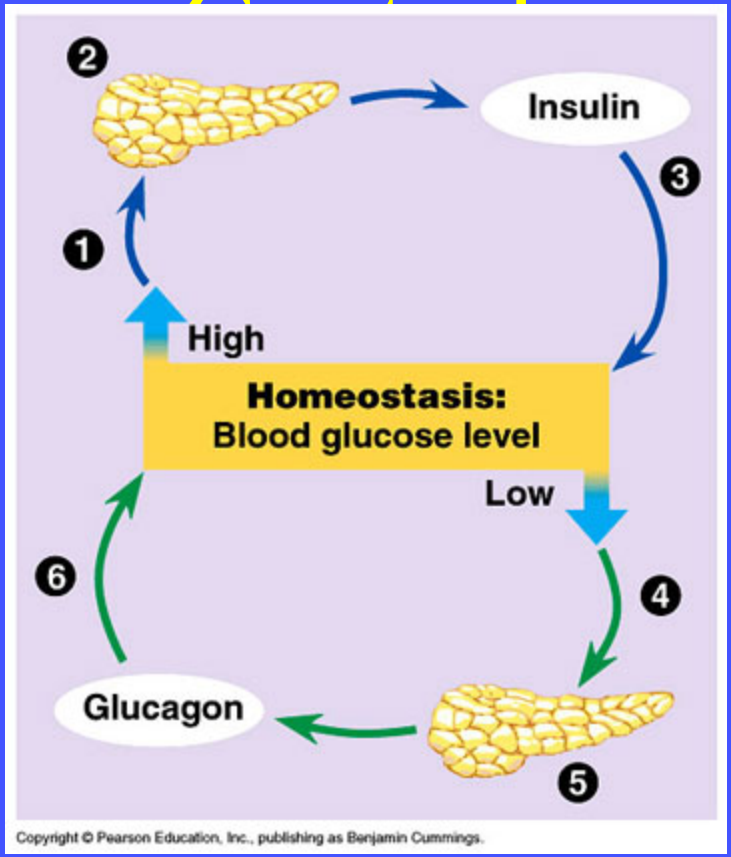
Counter-regulatory hormone excess (stimulated by high intensity exercise)

- ➡ Excess hepatic glucose release

Type 1 diabetes mellitus

- Insulin-producing β cells of the pancreas are targeted by the immune system
- insulin secretion becomes impossible
- external sources of insulin become necessary to maintain blood glucose control
- Can result in chronic hyperglycemia (high blood glucose) with serious long-term health problems

The Pancreas & Blood Glucose Control



Pre Participation Examination and Clearance

- History Questionnaire must include:
  - Do you have frequent urination?
  - Do you have excessive thirst?
  - Do you have frequent hunger?
  - Have you had any unexplained weight loss?
  - Do you have unexplained fatigue?
  - Do you have blurred vision?
  - Do you have a family history of diabetes? What type?
  - Do you have diabetes?

Pre Participation Examination and Clearance

- Existing Diabetes Type I Diagnosed Athletes must submit medical records documenting:
  - HbA1c testing (desired <7% for adolescent, <6% for adult)
  - Yearly dilated eye exam
  - Yearly kidney function exam
  - Yearly neurological exam
  - If they have been diabetic for >15 years, a graded exercise stress test should be performed
  - Type (s) and delivery method of daily insulin:
    - Insulin to carbohydrate ratio at meals
    - Sliding scale (correction factor) for high glucose
    - Pump basal rate(s) or long acting injected insulin

Pre Participation Examination and Clearance

- During Pre-participation Exam evaluate and discuss:
  - Diabetes self care skills
  - General physical exam
  - Educate athlete on effect of their sport on their diabetes
  - Make sure they have a medical alert tag
  - Athletes need to establish a relationship with a local endocrinologist
  - Complete a diabetes information sheet to keep in their chart and travel folder (see below)
  - Educate on proper foot care and foot wear for their sport
    - Inspect feet daily for blisters, abrasions, lacerations
    - Cut toe nails straight across
    - No walking barefoot
    - Avoid poor fitting shoes
  - Be aware of training limitations

Blood Glucose Monitoring and Insulin Therapy

- Pre exercise blood glucose should be 110-250 mg/dl
  - Check 2-3 times before exercise at 30 min intervals
  - Decrease the insulin bolus dose up to 50% at the pre exercise meal
- During exercise >1 hour blood glucose should be checked every 30 min
  - ≥250 mg/dl with ketones present—no activity allowed
  - ≥300 mg/dl no activity allowed

Blood Glucose Monitoring and Insulin Therapy

- Post exercise
  - Shortly after exercise, they should eat a snack or meal
  - If they tend to experience late onset hypoglycemia, measure blood glucose 2-4 hours post exercise and again before going to bed
  - Check once during the night if they experience nighttime hypoglycemia
  - If nighttime hypoglycemia reoccurs decrease the evening meal insulin bolus by 50%

Blood Glucose Monitoring and Insulin Therapy

- Insulin pump Use in Athletes
  - Decrease basal rate 20-50% 1-2 hours before exercise
  - Decrease bolus dose up to 50% at meal prior to exercise
  - Decrease bolus dose up to 50% one hour prior to activity
  - Disconnect the pump prior to exercise for no longer than one hour and monitor blood glucose frequently
  - Pump can be worn during non-contact sports. It is recommended you secure and pad the pump to decrease jostling during impact activities
  - Re-connect the pump immediately after competition
  - Check blood 30 minutes after reconnecting the pump to ensure proper function

Blood Glucose Monitoring and Insulin Therapy

- Strategies to optimize Insulin Therapy
  - Know the athlete's type of insulin used (both fast and long acting)
  - Know their dosages during the day
  - Know their corrections for high blood sugar (carb ratio, should be established between the athlete and their endocrinologist/nutritionist)
  - Know adjustment strategies for planned activities
  - Rotate injection sites for most effective insulin absorption
  - If having trouble with insulin therapy document blood sugar and insulin dosages for a week to have more information to relay to the endocrinologist/nutritionist

Emergency Situations: Hypoglycemia

- Signs and Symptoms
  - Early: hunger, irritability, drowsiness or confusion, rapid heart rate, sweating, dizziness, or loss of color, typically develops when the blood glucose is below 70 mg/dl
  - Late: brain neuronal glucose deprivation occurs and causes blurred vision, fatigue, difficulty thinking, decreased motor control, aggressive behavior, seizures, convulsions, and loss of consciousness
- Prevention
  - Frequent blood glucose monitoring
  - Carb intake adjustment pre-exercise or fast acting carb supplement during exercise
  - Insulin dose adjustments
  - Avoid exercising during peak of insulin
  - Prevent dehydration

Emergency Situations: Hypoglycemia

- Treatment
  - Check if they are alert and able to eat or drink without assistance
  - Administer 15 g of fast acting carbs (4 Dex4 tabs, 15 gm sports gel, 4 oz juice or soda)
  - Repeat glucose check every 15 min until blood glucose returns to normal range
  - Once glucose is up, give complex carbohydrate snack (bagel, sandwich)
  - If athlete is unconscious keep athlete on their side (hypoglycemia and glucagon can often cause nausea)
  - Call 911
  - Inject 1 mg glucagon in the upper thigh muscle (see instructions below)
  - Check glucose after 15 min
  - If still unconscious give a second glucagon dose if available
  - If consciousness is regained and athlete is able to swallow, provide food
  - Monitor closely for 2 hours, checking their glucose every 15-20 min

Emergency Situations: Hyperglycemia

- Signs and symptoms
  - Nausea, dehydration, decreased cognitive performance, decreased visual reaction time, sluggishness, fatigue
  - Ketosis: Also may have rapid breathing, fruity odor to breath, unusual fatigue, sleepiness, inattentiveness, loss of appetite, increased thirst, and frequent urination
- Prevention
  - Frequent blood glucose monitoring
  - Pre-exercise insulin dosage adjustments
  - Frequent blood glucose testing
- Treatment
  - Administration of small bolus of rapid acting insulin
  - When blood glucose is ≥250 mg/dl, test urine or blood for ketones; if ketones are moderate or high, exercise is contraindicated
  - When blood glucose is ≥300 mg/dl no activity is allowed

Sick Day Plan

- Check blood glucose (BG) every 4 hours around the clock until they are well
- Give BG correction (sliding scale) every 4 hours even if your child is not eating. Use novolog, humalog or apidra
- Test every urine for ketones or test blood ketones every 4 hours
- Offer fluids every 15 minutes while awake. If BG under 200, offer liquids with carbs. If BG over 200, offer sugar-free fluids.
- Call physician/911 for any ONE of these reasons:
  - Persistent vomiting (more than 3 times) with moderate to large urine ketones (or blood ketones greater than 1.5 mmol/l)
  - Altered behavior
  - Persistent rapid breathing

Sick Day Plan

- When you call, be prepared to provide:
  - The past 48 hours of blood sugars
  - Ketone levels
  - Any other symptoms your child may be experiencing
- For pump users:
  - If blood sugar over 240 and moderate or large ketones, give a correction for elevated blood sugar with a syringe and change site
  - Always continue the basal rate
- For shot takers:
  - Always give the basal insulin (lantus, NPH, or levemir)

Items to Have Access to at all Times

- Emergency contact information
  - Family members
  - Physicians-emergency help line to nurse and nutritionist
- Consent for treatment if they are a minor including consent to perform glucagon injection
- Have the athlete's diabetes information sheet (see Diabetes Care Plan)
- Athlete wears medical alert tag at all times

Items to Have Access to at all Times

- Blood glucose monitoring equipment including extra blood glucose test strips
- Supplies to treat hypoglycemia including glucose tablets, fruit juice, carbs, glucagon
- Supplies for urine or blood ketone testing
- Sharps container to properly dispose of needles and lancets
- Insulin and extra supplies (spare batteries, spare infusion sets and reservoirs for insulin pumps)
- A copy of the diabetes care plan

Performing a Glucagon Injection on a Diabetic Athlete

INJECTION OF GLUCAGON:

- Glucagon (1 mg) is the white powder in the vial.
- The appropriate dose for all adults is 1 mg.
- The syringe contains only water.
- Pop the cap from the glucagon vial
- Remove the cover from the needle on the syringe.
- Inject entire contents of the syringe into the vial (do not remove syringe)
- Gently mix (as indicated on the inside lid)
- Draw back the entire contents of the vial into the syringe
- Inject the entire contents into the upper thigh muscle
- Insert the full length of the needle

TYPE 2 DIABETES

Hypoglycemia can occur with oral agents

Many patients now on combination regimens (combined oral hypoglycemics / oral + insulin) requiring accounting for combined effects of each agent

May need to modify oral hypoglycemic regimen as response to insulin is enhanced

Weight loss is key to improving glycemic control (↓ insulin resistance) in many Type 2 diabetics

Target of 20-60 minutes moderate intensity exercise at least 4 days per week

Couple exercise regimen with diet planning to optimize treatment

SPECIFIC GUIDANCE BY TYPE OF DIABETES

TYPE 1 DIABETES

1. Estimate energy requirement of planned exercise
2. Pre-exercise planning:
   - Timing Intensity & Duration of Exercise
     - Pre-breakfast exercise typically lower risk for hypoglycemia
     - Decrease insulin / increase carbohydrate for increased intensity or duration
   - Carbohydrate Ingestion Before During and After Exercise
     - Type of carbohydrate important as is amount and frequency of ingestion
   - Insulin Adjustments
     - Type: short-acting allows easier adjustment

SPECIFIC GUIDANCE BY TYPE OF DIABETES

TYPE 1 DIABETES (cont'd)

3. Monitor blood glucose before, during and after exercise.

   - Watch *rate of change* as well as absolute glucose value

   - More frequent monitoring with new programs or modifications to training regimen.

   - More frequent monitoring with prolonged exercise or endurance events

Blood Glucose Exercise Guide:

(Pre-Exercise Values)

Ideal For Exercise: 120 – 180 mg%

BG	< 100 mg%	➡	Snack before exercise
BG	100-250 mg%	➡	Exercise
BG	>250 mg% (or ketones)	➡	Delay exercise, check ketones, address elevated glucose/ dehydration

SPECIFIC GUIDANCE BY TYPE OF DIABETES

TYPE 1 DIABETES (cont'd)

4. Insulin management:

Multi-dose regimen allows better flexibility

Insulin pump (Continuous Subcutaneous Insulin Infusion or CSII) may allow tighter titration

- reduce pre-meal insulin bolus and basal infusion rate during exercise (also post exercise for prolonged exertion)

Short Acting (Humulog/Lispro) preferable

- Wait 30 minutes after injection before exercise
- Decrease short-acting insulin pre-exercise

30% for exercise $\leq$ 1 Hr
40% for exercise 1-2 Hr
50% for exercise $\geq$ 3 Hr

Temporary Basal

- Enables patient to temporarily reduce or increase the active basal rate
- Accommodates for exercise or any substantial prolonged change in normal activity level
- All smart pumps have this feature

When to Use Temporary Basal

- Exercise - decrease
  - Start Temp Basal ~ 1 ½ to 3+ hours prior to exercise
  - End Temp Basal ~ 30 minutes to as much as 24hrs after exercise

  Less Activity - increase
  - Off season
  - Long Car Rides

Key Elements

- Dose
  - Amount of decrease or increase percentage
- Duration for temporary adjustment
- Test often to see a pattern

What to do with the Pump?

- Pre-exercise meal boluses may be reduced as much as 50% depending on when exercise will take place

- Basal Adjustments?
  - 0-20% decrease for exercise/activity of moderate intensity and short duration
  - 25-100% decrease for exercise/activity of moderate to high intensity and longer duration
  - Trial and error

Challenges

- Delayed onset hypoglycemia
  - What is it?
- Varying requirements for different activities
  - Testing to establish patterns and BG targets
- Supplemental snack may still be necessary for replacing glycogen stores lost during exercise

Tools for Success

- Target BG goals established
  - Exercise (e.g., 150 mg/dl)
- Test effectiveness of the settings
- Ability to adjust key elements for fine-tuning
- Understand *preventing* hypoglycemia is easier than treating

Insulin Pump Therapy and Exercise

- *Where do you carry it during exercise?*
- *Can you play contact sports?*
- *How often do you change the infusion site?*
- *You may give yourself a bolus of insulin for a high glucose reading*
- *You may adjust your basal delivery of insulin depending on your glucose readings (temporary basal rate)*

Variables

- **Blood flow differences**
  - **Activity**
  - **Site selection**
    - **Abdomen is fastest ~34 min***
    - **Deltoid, Femoral, Gluteal about the same (rapid-acting)**
  - **Ambient temperature**
    - **Hot, increased absorption**
    - **Cold, decreased absorption**
- **Dose size**
  - **Larger, longer**
  - **Smaller, shorter**
- **Weight**
  - **Insulin resistance**
- **Insulin quality**

**Insulin Aspart: A Fast-Acting Analog of Human Insulin*, Mudaliar S, et. Al.

Children on insulin pumps

- If basal insulin is set correctly, changes in meal scheduling due to exercise should not present a problem.
- Kids can disconnect their pump for 1 hour, test and correct if above target.
- They may need to eat a snack in order to bolus if they want to stay disconnected for a second hour. Two hours without any insulin is too long, this can lead to ketones. You can have ketones with a normal blood glucose reading.
- If they stay connected, they may need a temporary basal. This may need extended beyond the activity.

To Connect or Disconnect the Pump During Exercise or Competition?

- This may be left to the discretion of the individual
- Should not disconnect for more than one hour
- What are the rules for wearing a pump during competition?

Carbohydrate Calculator

- BG Correction Calculator
  - Input BG reading
  - Input personal Insulin Sensitivity Factor (ISF)
  - A correction dose is calculated
  - Correct back to target BG prior to exercise not normal range

CONCLUSION

- Benefits from exercise realized by non-diabetics can be achieved by diabetic patients as well (though metabolic gains typically are greatest for Type 2 DM).

- Guidelines for exercise in uncomplicated diabetes are the same as those for non-diabetics with the caveat of heightened vigilance for potential complications related to diabetes.

- Self blood glucose monitoring and flexible insulin regimens are key elements to successful pursuit of exercise in Type 1 DM

CONCLUSION

- Screening and adjustment for co-morbid condition in diabetes is crucial to avoid exercise related complications

- Adjustments for insulin must be individualized as there is much variation in insulin pharmacokinetics and glycemic response between Type 1 DM patients

Thank You

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