Mission POSSIBLE: Managing Glucose During Sports & Exercise

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What Is My Favorite Sport?

A. Miniature Golf
B. Accounting
C. Basketball

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Objectives

1. Explain the two-way relationship between glucose control and physical activity in people with diabetes
2. Offer practical recommendations for the prevention of hypoglycemia during and after exercise
3. Offer practical recommendations for the prevention of hyperglycemia and ketosis during exercise

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EXERCISE & BLOOD GLUCOSE CONTROL IS A

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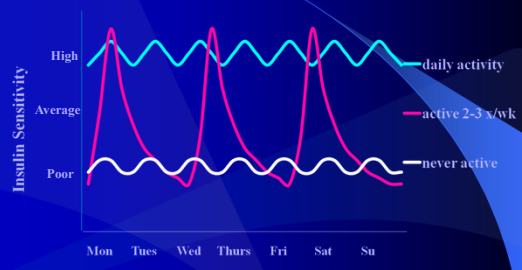
Activity levels affect insulin sensitivity **PROFOUNDLY**



Scheiner, G: Schematic representation of insulin sensitivity

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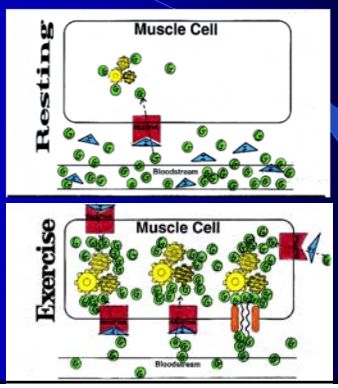
How Is Insulin Sensitivity Affected?



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Effects of post-meal walking

Study Results:

30 minutes of casual stop & go walking after meals

- ✓ **Avg. 30 mg/dl (1.75 mmol/L) reduction in post-meal glucose**
- ✓ **Post-meal peak reduced 45%**

Kudva, et al. Diabetes Care, published online Aug 8, 2012

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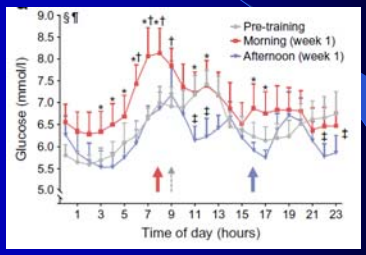
Does Time of Day Matter?



Afternoon exercise is more efficacious than morning exercise at improving blood glucose levels in individuals with type-2 diabetes: a randomized crossover trial

Diabetologia (2019) 62:233-237

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Blood Glucose Affects:

- ✓ Strength
- ✓ Stamina
- ✓ Speed/Agility
- ✓ Flexibility
- ✓ Safety
- ✓ Mental Sharpness

Sources: Colberg, Sheri: The Diabetic Athlete, Human Kinetics, Champaign, IL, 2001.
Walsh J et al: Using Insulin, Torrey Pines Press, San Diego, 2003.
Powers & Howley: Exercise Physiology, Wm C Brown Publishers, 1990.
Diabetes Exercise & Sports Association North American Conferences, 2004 through 2007

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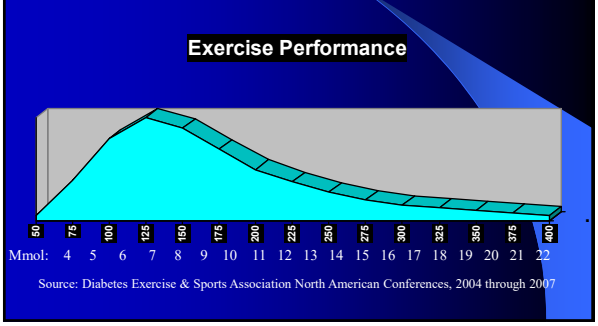
What BG Is Optimal?



Source: Diabetes Exercise & Sports Association North American Conferences, 2004 through 2007

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Overall Glucose Management Also Counts!

Prior Hyperglycemia Affects:

- ✓Hydration
- ✓Sleep Quality

Prior Hypoglycemia Affects:

- ✓Glycogen Storage
- ✓Sleep Quality

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Hypoglycemia Prevention

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Fuel Utilization During Exercise

1st 5-10 seconds	10 sec - ~ 10 min	~ 10 – ~30 min.	~ 30 min onward
Stored ATP/CP	Anaerobic Glycolysis	Oxidative (aerobic) metabolism	
	IM glucose	Hepatic Glycogenolysis	Hepatic Gluconeogenesis (FFA)
Likelihood of Hypoglycemia:	very low	moderate low	very high high

Scheiner, Gary, MS CDE

Source: Source: Brooks & Fahey: Exercise Physiology: Human Bioenergetics and its Applications, Macmillan Pub., NY, 1985.

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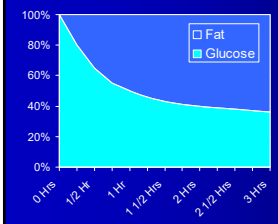
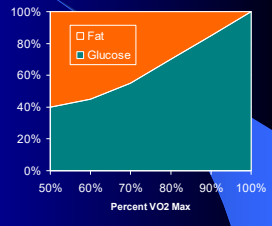
Energy Sources During Exercise

Substrate vs. Duration



BG drops more rapidly during 15-60 minute phase of prolonged exercise

Substrate vs. Intensity



BG drops more rapidly as exercise intensity increases

Scheiner, Gary, MS CDE

Source: Source: Brooks & Fahey: Exercise Physiology: Human Bioenergetics and its Applications, Macmillan Pub., NY, 1985.

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Hormonal Responses to Exercise (non-diabetic)

Insulin Secretion ↓↓

Counterregulatory Hormone Secretion ↑
• Epi/Nepi • Glucagon • GH, Cortisol

Substrate Breakdown
• Glycogenolysis
• Lipolysis
• A.A. Utilization

BG Holds *Steady* Despite ↑ Glucose Utilization by Muscle

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Hormonal Responses to Exercise
(diabetes, using insulin or insulin secretagogue)

Insulin Levels ⇗ or ⇔

Counterregulatory Hormone Action Suppressed

Substrate Breakdown Blocked
Glucose Uptake Accelerated

Hypoglycemia May Result

Scheiner, Gary, MS CDE
Source: Brooks & Fahey: Exercise Physiology: Human Bioenergetics and its Applications, Macmillan Pub., NY, 1985.

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Who Is At Risk of Hypogylcemia?

Premixed Insulin Users

MDI/Pump Users

Basal Insulin (Only) Users

Meglitinide Users

Sulfonylurea Users

Combination Med Users

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Med Adjustment Based on Timing and Duration

	Activity Within 2 Hours After Meal	Activity Before or Between Meals
Short Duration (<90 Minutes)	⇓ Mealtime Bolus (Omit Meglitinide)	Snack Prior to Activity

Derived from: Diabetes Care, vol. 24, no. 4, 4/2001, 625-630.

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Which is better for promoting weight loss?

- Exercise BEFORE eating?
- Exercise AFTER eating?

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Med Adjustment Based on Timing and Duration

	Activity Within 2 Hrs After Meal	Activity Before or Between Meals
Long Duration (>90 Minutes)	↓ Mealtime Bolus (omit meglitinide) ↓ Basal Rate Snack at regular intervals Watch for delayed-onset hypoglycemia	Snack Prior to Activity ↓ Basal Rate (if using pump) Snack at regular intervals Watch for delayed-onset hypoglycemia

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Insulin Adjustments

Meal Bolus Adjustment
(for post-meal activity)

- Low Intensity Cardio ↓ 25%
- Mod. Intensity Cardio ↓ 33%
- High Intensity Cardio ↓ 50%
- Competitive/Anaerobic ???

Derived from: Diabetes Care, vol. 24, no. 4, 4/2001, 625-630.
Source: Scheiner, Gary: Think Like A Pancreas, Marlowe Publishing, NY, 2005

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Insulin Adjustments

Basal Adjustment

(for > 90 min. activity)

- CSII: ↓ Basal rate 50-80% starting 1-2 hrs pre-activity, *or:*
- CSII: Disconnect 1-hr prior, but reconnect hourly and bolus 20-50% of usual basal rate

(for day-long activity)

- CSII: ↓ basal 50% daytime, 25% nighttime
- Injections: ↓ basal insulin 25% (night prior or morning)

Derived from: Diabetes Care, vol. 24, no. 4, 4/2001, 625-630.
Source: Scheiner, Gary: Think Like A Pancreas, Marlowe Publishing, NY, 2005

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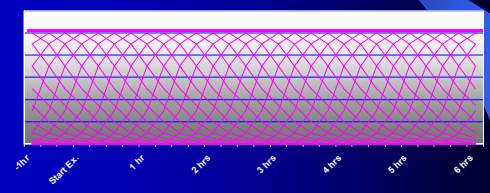
Pump disconnection: Effect on basal insulin level

Basal insulin is a series of minute boluses.



Based on observed pharmacodymanics of rapid-acting insulin analogs

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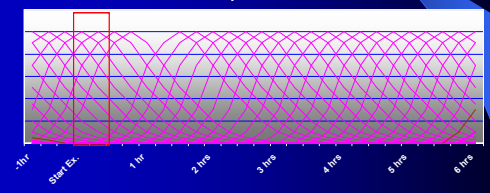
Pump disconnection: Effect on basal insulin level

Disconnection during 30 min. exercise (red box) eliminates bolus pulses for 30 minutes



Based on observed pharmacodymanics of rapid-acting insulin analogs

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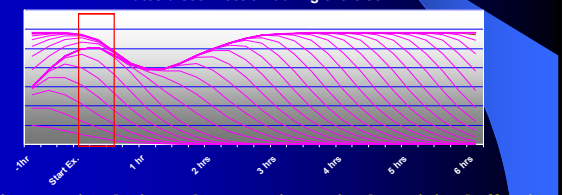
Pump disconnection: Effect on basal insulin level

Level of active basal insulin resulting from 30 minutes disconnection during exercise



Disconnection during a short exercise session has minimal effect !

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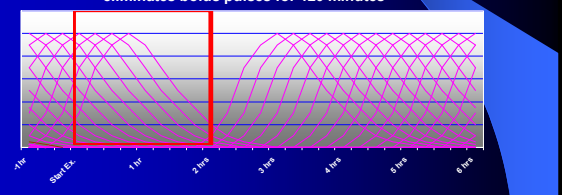
Pump disconnection: Effect on basal insulin level

Disconnection during 2 hours of exercise (red box) eliminates bolus pulses for 120 minutes



Based on observed pharmacodymanics of rapid-acting insulin analogs

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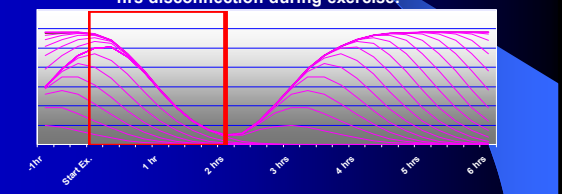
Pump disconnection: Effect on basal insulin level

Level of active basal insulin resulting from 2 hrs disconnection during exercise:



Disconnection for > 90 minutes has little benefit early on, and can result in a serious insulin deficiency later!

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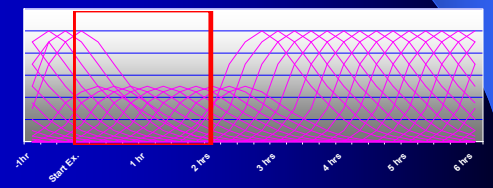
Pump Temp Basal: Effect on basal insulin level

Temp Basal -50% starting 1-hr prior to 2-hr exercise until 30 minutes before completion:



Based on observed pharmacodymanics of rapid-acting insulin analogs

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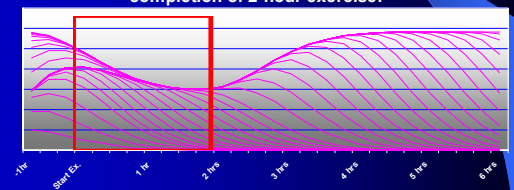
Pump temp basal: Effect on basal insulin level

Level of active basal insulin from temp basal -50% starting 1-hr prior until 30 minutes before completion of 2-hour exercise:



This approach results in a modest reduction in basal insulin throughout and immediately post-exercise.

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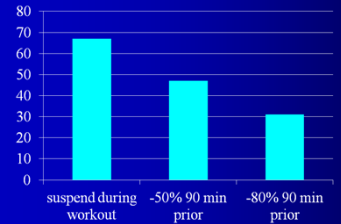
Suspension vs. Temp Basal

Glucose decline (mg/dl) during 60 minutes of moderate-intensity walking



Zaharieva D. Timing of insulin suspension pre-exercise affects hypoglycemia risk. Presented at the American Diabetes Association Scientific Sessions, Orlando, FL, June, 2018.

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Insulin Adjustment: Case Study

Pump wearer, 2-Hour Lacrosse Practice (after dinner)

⇩ Dinner bolus 50%

Disconnect 1-hr pre-practice, re-connect hourly & bolus 50% of usual basal

Snack at midpoint (if BG appears to be dropping)

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Snacking to prevent hypoglycemia

Basic Rules:

1. **Snack *prior* to activity to *prevent* hypoglycemia**
2. **Adjust quantity based on pre-activity BG or *direction* of BG**
   - BG low or dropping: ⇧ usual carbs
   - BG OK or stable: usual carbs
   - BG High or rising: ⇩ usual carbs
3. **Snack at least once per hour during prolonged activity**
4. **Choose high-glycemic-index forms of carbohydrate**
   - Sports drinks / Sweetened beverages
   - Dry cereal, pretzels, crackers

Source: Scheiner, Gary: Think Like A Pancreas, Marlowe Publishing, NY, 2005

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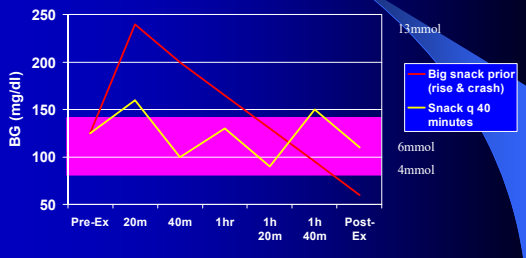
Which approach keeps BG in range for the majority of the workout?



Source: Scheiner, Gary, MS CDE

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Snacking to prevent a low

	Carbohydrate Requirement Per 60 Minutes of Activity (if no insulin adjustments are made)				
	50 lbs (24 kg)	100 lbs (48 kg)	150 lbs (71 kg)	200 lbs (95 kg)	250 lbs (119 kg)
Dancing or Gymnastics	8-12g	17-23g	25-35g	34-46g	42-57g
Tennis (singles)	18-22g	37-43g	55-65g	74-86g	92-107g
Swimming (fast pace)	22-25g	44-50g	65-75g	88-100g	110-125g

Sources: Scheiner, Gary: Think Like A Pancreas, Marlowe Publishing, NY, 2005
Walsh, John and Roberts, Ruth: Pumping Insulin, 4th ed., Torrey Pines Press, San Diego, 2006.
Heyward, Vivian: Designs for Fitness, Macmillan Publishing, NY, 1984.

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Snacking to prevent a low

	Carbohydrate Requirement Per 60 Minutes of Activity (if no insulin adjustments are made)				
	50 lbs (24 kg)	100 lbs (48 kg)	150 lbs (71 kg)	200 lbs (95 kg)	250 lbs (119 kg)
Cleaning Up	3-7g	7-13g	10-20g	14-26g	17-32g
Brisk Walking (mall/theme park)	8-12g	17-23g	25-35g	34-46g	42-57g
Mowing (push-mower)	13-17g	27-33g	40-50g	54-66g	67-82g

Sources: Scheiner, Gary: Think Like A Pancreas, Marlowe Publishing, NY, 2005
Walsh, John and Roberts, Ruth: Pumping Insulin, 4th ed., Torrey Pines Press, San Diego, 2006.
Heyward, Vivian: Designs for Fitness, Macmillan Publishing, NY, 1984.

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Snacking to prevent low: Case Study

After School Tennis (85 lb/40 kg)

- ✓ Check BG prior
- ✓ Snack 20g (if BG 161-200 / 9-11mmol)
- ✓ Snack 30g (if BG 100-160 / 5-9mmol)
- ✓ Snack 40g (if BG <100 / 5mmol)
- ✓ No snack (if BG >200 / 11mmol)
- ✓ Addl. 20g snack after each hr of play

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Hybrid Closed Loop Systems & Exercise

- Generally don't work well to prevent hypos during exercise
- May help prevent delayed-onset hypos
- Set temp target ↑↑ 2 hrs ahead (or switch to manual mode)
- Post-meal exercise: Enter less carb (or adjust bolus downward manually)

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V^{a}®i@eLΣ$:

Just a Few Factors that affect Blood Glucose During Exercise

- Active Insulin
- Infusion Site
- What You Ate
- Time of Day
- Emotional State
- Temp/Humidity
- Familiarity w/Activity
- Amt. Of Prior Activity
- Size/Number of Muscles Involved
- **Duration**
- **Intensity**

Sources: Walsh J et al: Using Insulin, Torrey Pines Press, San Diego, 2003.
Scheiner, Gary: Think Like A Pancreas, Marlowe Publishing, NY, 2005.

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Watch Out for *D'OH!*

(Delayed Onset Hypoglycemia)

- Following high-intensity exercise
- Following extended duration activity
- Due to replenishment of muscle glycogen stores, enhanced insulin sensitivity
- May occur up to 24 hours afterwards (typically 6-12 hours later)

Source: Colberg, Sheri: The Diabetic Athlete, Human Kinetics, Champaign, IL, 2001.

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D'OH! Prevention

- Keep records – track the patterns
- Decrease basal insulin (modestly) or meal/snack boluses post-activity
- "Free" Snacks (slow-acting carbs) following activity

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D'OH! Prevention

- **Check BGs more frequently**
  - ✓ q 2 hrs during "high risk" period
  - ✓ 3am night following heavy activity
- **Wear a continuous glucose monitor**

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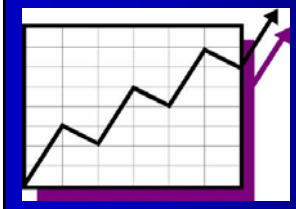
Can Exercise *Cause*



Rise in BG?

Ketoacidosis?

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Blood Glucose Homeostasis: The Grand Balancing Act

↓ Muscle Activity

↓ Insulin

↑ Carbohydrate

↑ Counterregulatory / Stress Hormones

Adrenaline Raises BG!

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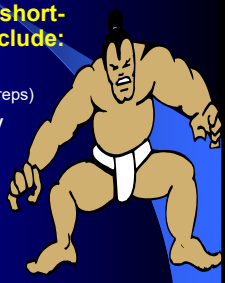
Adrenaline Raises BG!

Activities that often produce a short-term blood glucose rise include:

- ↗ **Weight lifting** (high weight, low reps)
- ↗ **Sports w/ "bursts" of activity** (golf, baseball, martial arts)
- ↗ **Sprints** (running, swimming)
- ↗ **Judged performances** (gymnastics, skating)
- ↗ **Events in which WINNING is the primary objective**



Sources: Colberg, Sheri: The Diabetic Athlete, Human Kinetics, Champaign, IL, 2001.

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Preventing / Offsetting BG Rise

- ✓ **Keep Records to determine avg. BG rise**
- ✓ **Check BG 30-60 Min. Pre-Activity**
  - ✓ **Bolus 30-60 min. prior to activity to offset rise (give 50% of usual amount required)**
  - ✓ **Take 50% of Usual "Correction Dose" If High (reduce based on insulin-on-board)**

Sources: Scheiner, Gary: Think Like A Pancreas, DaCapo Press, 2012

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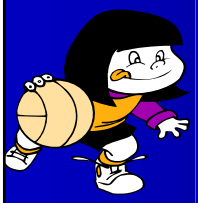
Snacking to prevent high: Case Study



Late-Morning Basketball; disconnects for 1 hour; BG typically rises from 100 to 300mg/dl (5.5 to 16.6 mmol).

- ✓ Check BG 30 min prior
- ✓ Bolus 50% of amount required to cover current BG (including IOB)
- ✓ Bolus 50% of amount needed to offset 200 mg/dl (11 mmol) rise
- ✓ Check BG at halftime; keep sugared drinks handy.

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Post-Workout Rise?

Possible Causes:

- Pump suspension / disconnection
- Delayed food digestion
- Excess carbs during workout
- Latent stress hormones

Possible Solutions:

- Post-workout bolus
- Delay all (or part) of meal bolus
- Limit suspension / disconnection time
- Appropriate carb supplementation

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How High is Too High?

No Such Number.

✓ Performance may suffer
✓ Hydrate
✓ Administer Rapid-Acting Insulin (i.m.?)

The Exception: Ketosis

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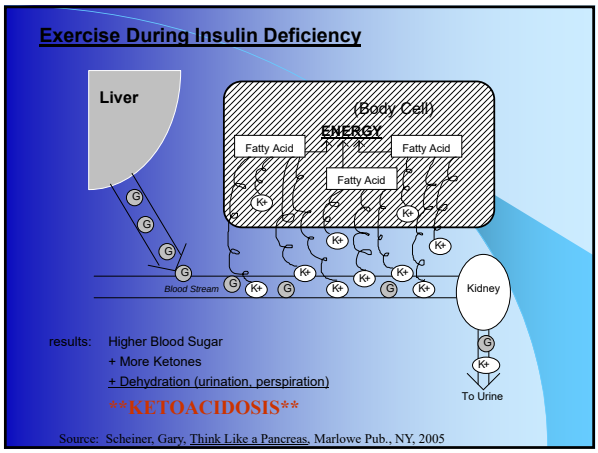
Exercise During Insulin Deficiency
Liver
(Body Cell)
ENERGY
Fatty Acid
Fatty Acid
Fatty Acid
Blood Stream
Kidney
To Urine
results: Higher Blood Sugar
+ More Ketones
+ Dehydration (urination, perspiration)
KETOACIDOSIS
Source: Scheiner, Gary, Think Like a Pancreas, Marlowe Pub., NY, 2005

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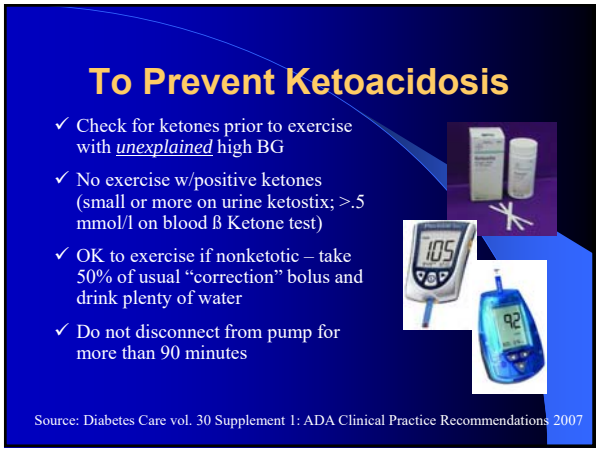
To Prevent Ketoacidosis
✓ Check for ketones prior to exercise with unexplained high BG
✓ No exercise w/positive ketones (small or more on urine ketostix; >.5 mmol/l on blood ß Ketone test)
✓ OK to exercise if nonketotic – take 50% of usual "correction" bolus and drink plenty of water
✓ Do not disconnect from pump for more than 90 minutes
Source: Diabetes Care vol. 30 Supplement 1: ADA Clinical Practice Recommendations 2007

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Alternatives to extended pump disconnection
Wear It!
✓ Clip to tight clothing
✓ Sport Pack
✓ Fanny Pack
✓ Backpack Harness

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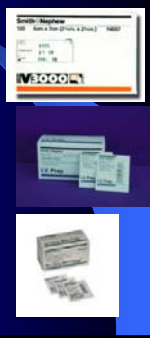
Infusion Set & CGM Adhesion During Exercise

✓**Smart Set Placement**
- ➢ Under tight clothing
- ➢ Body part w/less skin movement

✓ **Skin prep agent w/adhesive** (IV Prep, Skin Prep, Mastisol)

✓ **Tape over site** (GrifGrips, Infusion Set IV 3000, Dexcom overtape)

✓ **Antiperspirant** (Hypercare 20% AlCl solution, Stratus Pharma.)



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Pump & Temperature Extremes During Exercise

Cold:

Generally not a concern when pump is worn against body

Heat:

Insulin analogs can denature if:
- ➢Exposed to > 98°F (36C)
- ➢Stored or worn > 86°F (30C) for extended periods

Pump function OK under most conditions

Sources: insulin package inserts, insulin pump manufacturers

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Pump & Temperature Extremes During Exercise

"Cool" Ideas:

✓ Keep pump out of direct sunlight
- • Wear under clothing
- • Store in a cool place when disconnected
- • Don't forget the tubing!!!

✓Spend less time in extreme heat
- • Get into a/c and shade periodically
- • Humidity is not a factor

✓ FRIO Cooling Case

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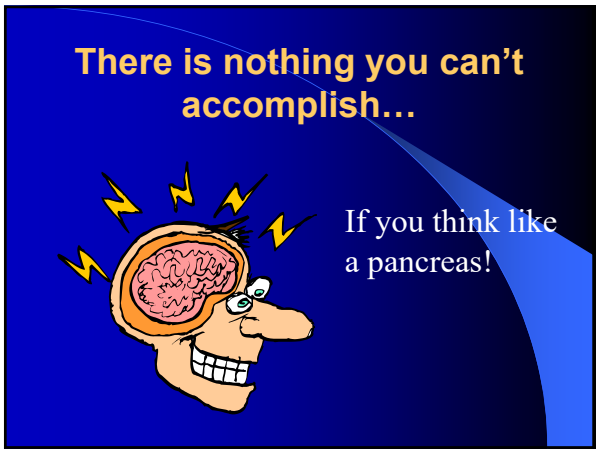
There is nothing you can't accomplish…
If you think like a pancreas!

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