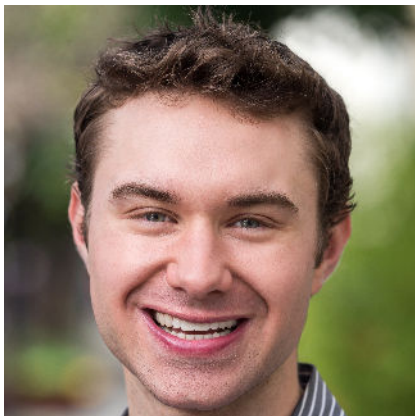


42

Factors That Affect Blood Glucose



As a person with diabetes, I always fall into the trap of thinking I'm at fault for out of range blood sugars. But after 17 years living with diabetes, I've learned that there are all kinds of factors that affect blood glucose, many of which are impossible to control, remember, or even account for.

Based on personal experience, conversations with experts, and scientific research, here's a list of **42 factors** that affect blood glucose. I've provided arrows to show the general effect these 42 factors have on *my* blood glucose, or the effect they seem to have on blood glucose based on research.

However, not every individual will respond in the same way, so the best way to see how a factor affects you is through personal experience – check your blood glucose more often with a meter or wear a CGM and look for patterns.

– Adam Brown for **diaTribe.org** | **@diaTribenews**

diaTribe Learn

Food

- ↑ ↑ 1. Carbohydrate quantity
- ↑ 2. Carbohydrate type
- ↑ 3. Fat
- ↑ 4. Protein
- ↑ 5. Caffeine
- ↓ ↑ 6. Alcohol
- ↓ ↑ 7. Meal timing
- ↑ 8. Dehydration
- ? 9. Personal microbiome

Medication

- ↓ 10. Medication dose
- ↓ ↑ 11. Medication timing
- ↓ ↑ 12. Medication interactions
- ↑ ↑ 13. Steroid administration
- ↑ 14. Niacin (Vitamin B3)

Activity

- ↓ 15. Light exercise
- ↓ ↑ 16. High-intensity and moderate exercise
- ↓ 17. Level of fitness/training
- ↓ ↑ 18. Time of day
- ↓ ↑ 19. Food and insulin timing

Biological

- ↑ 20. Insufficient sleep
- ↑ 21. Stress and illness
- ↓ 22. Recent hypoglycemia
- ↑ 23. During-sleep blood sugars
- ↑ 24. Dawn phenomenon
- ↑ 25. Infusion set issues
- ↑ 26. Scar tissue and lipodystrophy
- ↓ ↓ 27. Intramuscular insulin delivery
- ↑ 28. Allergies
- ↑ 29. A higher glucose level
- ↓ ↑ 30. Periods (menstruation)
- ↑ ↑ 31. Puberty
- ↑ ↓ 32. Celiac disease
- ↑ 33. Smoking

Environmental

- ↑ 34. Expired insulin
- ↑ 35. Inaccurate BG reading
- ↓ ↑ 36. Outside temperature
- ↑ 37. Sunburn
- ? 38. Altitude

Behavioral & Decision Making





- ↓ 39. Frequency of glucose checks
- ↓ ↑ 40. Default options and choices
- ↓ ↑ 41. Decision-making biases
- ↓ ↑ 42. Family relationships and social pressures

Food Factors






That Affect Blood Glucose

Factor	Typical Effect on BG	Comments
1. Carbohydrate Quantity	↑↑	Of all the three sources of energy from food (carbohydrates, protein, and fat), carbohydrates affect my blood glucose the most. Accurately counting carbs is very difficult, and getting the number wrong can dramatically affect blood glucose. The type of carbohydrate also matters – higher glycemic index carbs tend to spike blood glucose more rapidly.
2. Carbohydrate Type	↑→	As I've written before , not all carbs are created equal. My personal major sources of carbs – green veggies, nuts, seeds, chia pudding, low-carb/high-fiber tortillas, berries – tend to have 50%-80% of the carbs from <i>fiber</i> and are very low in sugar. Foods with a high-fiber-to-total-carbs ratio have a lower impact on my blood glucose vs. foods with the same amount of total carbs but no fiber. In addition, the more grams of carbs that come from sugar, the higher the impact on blood glucose – even if total carbs are the same. Last, format also matters <i>so much</i> – liquid carbs will usually increase blood glucose more quickly than solid carbs, even if the overall carbs are equal.
3. Fat	↑→	Fatty foods tend to make people with diabetes more insulin resistant, meaning more insulin is often needed to cover the same amount of food relative to a similar meal without the fat. The hardest meals are those with lots of fat and lots of carbs. On my pump, I sometimes use temporary basals or extended boluses (square and dual-wave) to cover high-fat meals. The effect is most notable if you eat a lot of fat at one time – for instance, when snacking on nuts, I'll observe a steady rise in blood glucose over many hours.
4. Protein	↑→	If you've ever eaten a protein-only meal with very few carbs (e.g., salad with chicken), you may have seen a noticeable rise in blood glucose (~20-50 mg/dl). Though protein typically has little effect on blood glucose, in the absence of insulin, it can raise blood glucose. When I'm eating a carb-free, protein-only meal, I still take a bit of insulin to cover it (usually an equivalent of about 10-15 grams of carbs). I've found pure protein powders (with no carbs) can increase blood glucose quite a bit – sometimes by 30-50 mg/dl.
5. Caffeine	↑→	Many studies have suggested that caffeine increases insulin resistance and stimulates the release of adrenaline. Personally, I know that if I have a large cup of coffee, I'll see at least a 20-30 mg/dl rise in blood glucose, particularly in the morning when I'm more insulin resistant. I also see this with tea, but to a smaller extent.






Food Factors That Affect Blood Glucose

6. Alcohol		Normally, the liver releases glucose to maintain blood sugar levels. But when alcohol is consumed, the liver is busy breaking the alcohol down, and it reduces its output of glucose into the bloodstream. This can lead to a drop in blood sugar levels if the alcohol was consumed on an empty stomach. However, alcoholic drinks with carbohydrate-rich mixers (e.g., orange juice) can also raise blood sugar. When drinking alcohol, make sure you check your blood glucose often and that someone responsible nearby knows you have diabetes.
7. Meal Timing		I've found eating a large late-night dinner often results in high overnight blood sugars (over 180 mg/dl), especially if it's a meal high in carbs and fat. The converse is also true: a lighter, earlier dinner seems to improve my overnight numbers, which remain in the range of 70-140 mg/dl.
8. Dehydration		Over the years, several diaTribe readers have emailed sharing that dehydration seems to increase their blood glucose levels. Indeed, in a randomized, controlled 2001 study, dehydration did raise blood glucose levels for those in a fasted state (Burge et al., Metabolism). <i>The New York Times</i> also reported in 2012 that dehydration increases levels of the hormone vasopressin, which pushes the liver to produce blood sugar (Anahad O' Connor, January 16). Luckily, it's becoming easier and easier to find water, so this is a great way to be proactive.
9. Personal Microbiome		There is a lot of ongoing research on the impact of gut bacteria ("microbiome") on blood glucose levels and insulin sensitivity. Dr. Eran Segal's lab at the Weizmann Institute has done some compelling work on this topic with microbiome data, summarized in a great TED talk: What is the best diet for humans? They have published a number of high profile papers , including one on how gut bacteria predicts an individual's glucose response to bread (Cell Metabolism 2017), another on personalized nutrition with CGM and microbiome data (Cell 2015), and a third on how artificial sweeteners negatively affect the microbiome and glucose responses (Nature 2014).

Medication Factors That Affect Blood Glucose

10. Medication Dose		For those of us with diabetes on any medication (pills or insulin injections), the dose of medication directly impacts blood glucose – in most cases (but not always), taking a higher dose of a diabetes medication means a greater blood glucose-lowering effect.
11. Medication Timing		In addition to dose, medication timing can also be critical. For instance, taking rapid-acting insulin (Humalog, Novolog, Apidra) 20 minutes before a meal is ideal for me – it leads to a lower spike in glucose vs. taking it at the start of the meal or after the meal has concluded. The timing of many type 2 diabetes medications matters a lot too – some can consistently be taken at any time of day (e.g., Januvia, Victoza), while others are most optimally taken at meals (e.g., metformin).
12. Medication Interactions		Non-diabetes medications can interfere with your diabetes medications and blood glucose. Consult the information included in both your diabetes and non-diabetes medications.
13. Steroid Administration		While this is technically included in “medication interactions,” many frustrated diaTribe readers have emailed us on this topic – hence calling it out separately. Steroids like prednisone can significantly increase blood glucose levels, in part by telling the liver to increase glucose production. This Joslin article reports that once prednisone is stopped, blood glucose levels usually return to normal fairly quickly.
14. Niacin (Vitamin B3)		Studies show niacin does increase blood glucose levels modestly . Niacin is typically prescribed to improve blood lipid levels, including HDL cholesterol and triglycerides (i.e., to improve heart health). According to a Medscape article (based on a 2005 study), the increased blood glucose levels seen with niacin did not translate into worse heart outcomes. Still, this is another factor to keep in mind if your glucose levels are higher than expected.

Activity Factors That Affect Blood Glucose

15. Light Exercise		Light activity can have a surprising glucose-lowering effect – I find that walking tends to lower my blood sugar by about 1 mg/dl per minute. I have seen drops as large as 46 mg/dl in 20 minutes, more than 2 mg/dl per minute, and others see even more.
16. High Intensity and Moderate Exercise		Exercise is often positioned as something that <i>always</i> lowers blood glucose; however, high-intensity exercise, such as sprinting or weight lifting, can sometimes raise blood glucose. This stems from the adrenaline response, which tells the body to release stored glucose. Often, I find this happens when I'm exercising in the morning on an empty stomach. But this is not a reason to avoid high intensity exercise – studies show it can improve blood glucose for one to three days post-exercise! Note that in some cases high-intensity exercise can also drop blood glucose very rapidly (2-3 mg/dl per minute), especially if you took insulin prior to exercise. The best way to see how individual exercise sessions affect your blood glucose is to test before and after activity.
17. Level of Fitness/ Training		Back when I started cycling in 2011, I would see dramatic drops in blood glucose. Now that I'm more accustomed to it, I see smaller glucose drops for the same amount of time cycling. This factor is especially important for someone starting a new activity (or starting any exercise); you may see profound blood glucose drops initially, which may get smaller over time as level of fitness improves.
18. Time of Day		I find <i>morning</i> exercise causes a smaller drop in blood glucose, at least relative to other times of day. I tend to be more insulin resistant in the morning, which could explain the effect. Kelly (<i>diaTribe's</i> Editor-in-Chief) is the opposite and is much more insulin sensitive in the morning! Your mileage may vary, and understanding more about your morning sensitivity is especially possible through CGM.
19. Food and Insulin Timing		One common timing mistake: eating too close to starting exercise, which can cause low glucose during activity (food has not been absorbed) followed by a significant high afterwards. Other insulin-related exercise mistakes are also common: not reducing bolus insulin enough and suspending basal insulin (pump) immediately before activity. These are covered in more detail in chapter 3 of my book, Bright Spots & Landmines .

Biological Factors That Affect Blood Glucose

20. Insufficient Sleep	↑	I have found that I need nearly 25% more insulin on days following less than seven hours of sleep; my highest blood glucose of the day is even higher on days following little sleep; and my glucose is 21% more variable when I do not sleep enough. These findings are consistent with many studies, which have found that not getting enough sleep leads to higher blood sugars, insulin resistance, weight gain, increased food intake, and more carb cravings.
21. Stress and Illness	↑	Stress and illness can cause the body to release epinephrine (adrenaline), glucagon, growth hormone, and cortisol. As a result, more glucose is released from the liver (glucagon, adrenaline) and the body can become less sensitive to insulin (growth hormone, cortisol). Personally, I have found exercise, time outside, and meditation to be most helpful against combatting stress.
22. Recent Hypoglycemia	↓	This phenomenon is sometimes called “hypoglycemia begets hypoglycemia.” For instance, if I’ve experienced hypoglycemia in the past 12 hours, I’m more likely to experience hypoglycemia again. One reason for this “vicious cycle,” as explained in a 1993 article by world renowned hypoglycemia expert Dr. Philip Cryer, is that recent hypoglycemia impairs the body’s defense mechanisms against lows. When another low comes up, it’s harder to recognize the symptoms and/or the body has a harder time avoiding it. This was seen in the study testing the MiniMed 530G’s low glucose suspend feature, as well as in at least one CGM study .
23. During-sleep Blood Sugars	→ ↑	My overnight blood sugars seem to have a big impact on my next-day time-in-range (70-140 mg/dl): if I spend all night high – especially over 180 mg/dl, I’m more likely to fight high blood sugars the whole next day. Conversely, when I spend most of the night in range, the next day gets off to a far better start, and I seem to spend more time in range. I have not been able to find research on overnight time-in-range driving next-day time-in-range, but my own CGM data has confirmed this time and time again.
24. Dawn Phenomenon	↑	The “dawn phenomenon” occurs in people with and without diabetes. The term refers to the body’s daily production of hormones around 4:00-5:00 AM. During this time, the body makes less insulin and produces more glucagon, which raises blood glucose. The best way to figure out how dawn phenomenon affects you is to wear a CGM or wake up and check your blood glucose early in the morning with a meter. If you take insulin, you may need to time your dose to cover this early morning rise in glucose. Note that not everyone experiences dawn phenomenon, but it is common!

Biological Factors That Affect Blood Glucose

25. Infusion Set Issues		Infusion sets are not as well understood as we would like, and a huge number of factors can lead to higher glucose levels: air bubbles in the tubing, an occluded cannula, an infected site, or even the location of the set. If you wear a pump and your glucose is unexpectedly high, a good first step is to change your set out. I find that my glucose always tends to run higher on the third day of wearing an infusion set. In addition, I tend to get the best absorption wearing sets in my buttocks and the worst absorption in my legs – yet again, this varies by person.
26. Scar Tissue & Lipodystrophy		Using the same sites on the body for injections or infusion sets can lead to lipodystrophy and scar tissue buildup – these result in erratic absorption of insulin, leading to glycemic variability and making it harder to spend more time in range. To avoid these issues, rotate your injection/infusion sites and don't reuse needles.
27. Intramuscular Insulin Delivery		Here's another one for people on insulin! Injecting or pumping insulin into a muscular/low-body-fat area can increase the risk of hypoglycemia – especially if it happens before activity. For instance, when I go for a bike ride, I see a far bigger drop in blood sugar when my pump site is on my leg vs. other locations. My friends on injections have shared similar sentiments.
28. Allergies		Though I have not found any studies on this topic, some patients report higher glucose levels when they have allergies. Some have speculated that it's due to the stress hormone cortisol.
29. A Higher Glucose Level		Hyperglycemia can lead to a state known as “glucotoxicity,” which can actually cause insulin resistance. Have you ever needed to correct a very high blood sugar with much more insulin than your correction factor would suggest? I find that simply having a high blood glucose for many hours makes me appear much more insulin resistant.
30. Periods (menstruation)		There is not a definite answer to the question of how periods affect women's blood sugars. Many women report having higher blood sugar levels a few days prior to their period starting, but some women notice a sharp drop in sugar levels. To figure out how you respond, your best bet is to check your blood glucose more often during this time of month.




Biological Factors That Affect Blood Glucose

31. Puberty	↑↑	High levels of hormones secreted during puberty – growth hormone, testosterone, estrogen, cortisol – can increase insulin resistance. According to some estimates , adolescents with diabetes may need as much as 30%-50% more insulin than adults to keep their numbers within range. JDRF has a valuable teen toolkit with more details.
32. Celiac Disease	↑↓	Untreated celiac, leading to a damaged small intestine, can increase the risk of hypoglycemia because the small intestine may no longer be able to absorb nutrients properly. Beyond Celiac also notes that untreated celiac may contribute to “irregular blood glucose levels.” According to the Celiac Disease Foundation , ~6% of people with type 1 diabetes have celiac, which is six times higher than the general population. There is no established link between type 2 diabetes and celiac disease.
33. Smoking	↑	Some studies suggest that smoking can increase insulin resistance, and people with diabetes who smoke are more likely than non-smokers to have trouble with insulin dosing and managing their diabetes. Smokers also have higher risks for serious complications.



Environmental Factors That Affect Blood Glucose

34. Expired Insulin	↑	I've fried my insulin by exposing it to direct sunlight or leaving it in the car on a hot day. If your insulin is normally clear, but suddenly turns cloudy, that could signal it has gone bad (note: NPH is always cloudy). Aside from a change in appearance, it can be hard to know if a vial of insulin has actually gone bad unless you try a new one. I've found that insulin that has “gone bad” will typically still work, but just not as well – I may need more insulin than I think to bring my glucose down, and the insulin may work unpredictably. Unopened insulin should be stored in a refrigerator at approximately 36-46 °F. According to the FDA, insulin can be left unrefrigerated at a temperature from 59-86 °F for up to 28 days.
35. Inaccurate BG Reading	↑	While this seems fairly obvious, I often find myself checking multiple times in a row, since I do not believe the initial value on the meter – in many cases, the second time I get a much lower value, and it's because I failed to wash my hands before a fingerstick. For a meter that needs a tiny 0.3 microliter blood sample (the smallest currently on the market), a speck of glucose on the finger the weight of a dust particle will increase the reading by 300 mg/dl! I recommend rechecking if the value on the meter is far different from how you feel. If you wear CGM, it's great to reality check the meter value against your sensor reading.

Environmental Factors That Affect Blood Glucose

36. Outside temperature		<p>This scientific review on body temperature regulation in diabetes (2016) summarizes a lot of research and I was struck by some evidence that cold exposure can improve insulin sensitivity in type 2 diabetes. Some people with diabetes also report that sitting in the sun drops their blood glucose – this blog post from Columbia's Dr. Jane K. Dickinson hypothesizes that the blood vessel dilation from heat might be responsible (similar to the effect in a hot shower or hot tub). In the comments section, others confirm that cold weather drives their glucose numbers down – perhaps related to the body working harder (shivering) to stay warm. More research is clearly needed, especially to disentangle temperature from other related factors (exercise, hydration, meter accuracy, expired insulin), but there is more than a signal that outdoor temp is an independent biological factor that affects BG.</p>
37. Sunburn		<p><i>diaTribe</i> readers, along with many sources (CDC, Cleveland Clinic, ADA), note that sunburn stresses the body and can increase blood glucose. This is related to “stress/illness,” but since sunburn is so common and non-obvious, it is called out specifically here.</p>
38. Altitude		<p>Though most studies related to diabetes and altitude concern the accuracy of blood glucose meters, there are some reports that altitude can increase insulin resistance. I've found that when I go to high altitude regions like Colorado, I need about 20-30% <i>more</i> basal insulin. However, if you go to a high altitude place to do activity (e.g., skiing), you may find that you need <i>less</i> insulin.</p>

Behavioral & Decision-Making Factors That Affect Blood Glucose

39. Frequency of glucose checks		<p>More frequent glucose data ensures I'm driving my diabetes safely and able to steer my blood glucose back onto the road (in range) if I'm going high or low. Plus, glucose data provides useful feedback on what I did well or what I might do differently next time. In studies of both fingersticks and CGM, the more frequently someone obtains a glucose reading, the better they do (higher time-in-range, less hypoglycemia, lower A1c, etc.) Some might believe that glucose-check frequency is simply a marker of diabetes motivation (correlation), but I personally disagree. Glucose data is a key factor in diabetes decision making and learning.</p>
40. Default options and choices	 	<p>Small tweaks in the environment – or the way different options are presented – can really impact our choices. In turn, those choices directly impact our blood glucose, especially related to eating and insulin dosing. Here are two I think about a lot, based on great books I've read on this topic (Nudge, Switch, Mindless Eating, and The Undoing Project):</p> <ul style="list-style-type: none"> • Plate/bowl size: the same food on a smaller plate looks more filling. At diaTribe, we highly recommend switching to 8-inch dinner plates. The same is also true of bowls – the larger the bowl, the more you will eat. • Visual prompts (keeping junk food out of sight): When there is junk food sitting around – especially if it's highly visible on the counter – I'm more likely to eat it. When bread is brought to the table at a restaurant, I'm more likely to have a nibble, and then two, and then finish half a loaf. When I store glucose tabs everywhere in my life, I'm far more likely to treat my low with a predictable correction, rather than opening the fridge and binging. In short, the visual prompts in my environment directly impact what I choose, driving big changes in blood glucose.

Behavioral & Decision-Making Factors That Affect Blood Glucose

41. Decision-making biases



I think these five biases have an especially notable impact on choices and blood glucose levels – it might sound a bit geeky, but stay with me here!

Present bias (Hyperbolic Discounting): When given two similar rewards, most of us prefer the reward that arrives sooner rather than later. Would you prefer \$5 right *now* or \$10 in three weeks? This is arguably the biggest challenge in diabetes – it's easier to prioritize what feels good *now* rather than the longer-term benefits of keeping blood sugars in range. This affects food choices in a huge way, but also motivation to exercise. It's easy to make the wrong choice – and see resulting high blood sugars – when the feel-good benefits of doing so are immediate.

Loss aversion: We tend to prefer avoiding losses rather than acquiring equivalent gains: it's better to *not lose* \$10 than to find \$10. Hypoglycemia is the best example of a *loss* that everyone with diabetes wants to avoid. This can lead to accepting more time with high blood sugars, especially for those without access to CGM or strips. Loss aversion impacts all sorts of diabetes choices, such as what glucose target to aim for (e.g., 150 vs. 100 mg/dl), when to correct a high blood sugar, what blood sugar to go to sleep with, and more.

Negativity bias: It's easier to recall unpleasant memories compared with positive memories. This is the thesis of [Bright Spots & Landmines](#) – we all tend to focus on the things going wrong, which puts our focus on mistakes and self-blame. This focus on the negative is sometimes helpful, but can also lead to a lot of guilt, frustration, and depleted motivation. Finding Bright Spots – those things that are *working* and should be replicated – helps overcome the negativity bias and has had a big positive impact on my blood sugars.

Selective matching: People often perceive patterns where none exist. For those with arthritis, this might mean looking for changes in the weather when experiencing increased pain, but paying little attention to the weather when pain is stable. As Dr. Amos Tversky summarized [in 1995](#), “[A] single day of severe pain and extreme weather might sustain a lifetime of belief in a relation between them.” Since there are so many factors that affect blood glucose, it's easy to draw inaccurate conclusions about cause-and-effect. For instance, the one time I ate ____, my blood sugar stayed in-range – therefore, this is a great food to eat. In reality, I always try to confirm my blood-sugar hypotheses with multiple experiments and tests.

Representative bias: When evaluating a situation, the most immediate examples that come to mind often drive the decision – even if those aren't representative of the real trend. For instance, after one night spent with low blood sugars, I'm often tempted to change my whole insulin regime, even if the previous six nights had no lows.

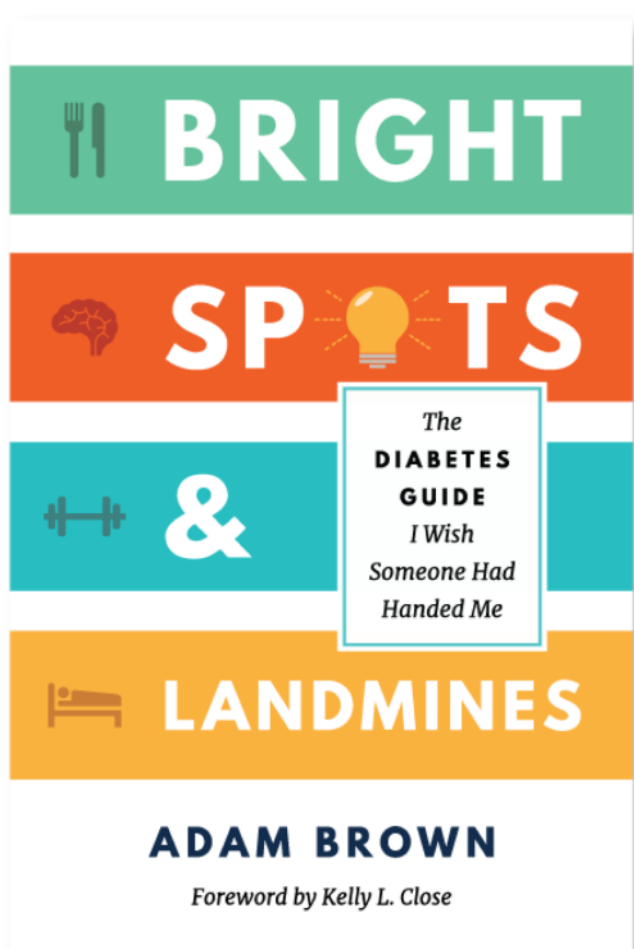
42. Family relationships and social pressures



At the recent JDRF Mission Summit, psychologist Dr. Weissberg-Benchell pointed out the link between diabetes distress and blood glucose outcomes. Interestingly, she mentioned how [high levels of family conflict](#) and family distress are linked to higher A1c's in kids/teens with diabetes. On this point I'd add social pressures, as I mentioned in a [recent column](#) about choosing what to eat at a pizza restaurant. To me, this is another factor worth calling out – a challenging family or social environment can directly impact blood sugars.

For tips to conquer the 42 Factors, download
Bright Spots & Landmines

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