

A blue-tinted electron micrograph showing several mitochondria with their characteristic internal folds (cristae). The mitochondria are arranged in a somewhat circular pattern across the frame.

# Measuring Mitochondrial Dysfunction In Real Time: Insulin and Continuous Glucose Monitoring

**Robert H. Lustig, MD, MSL**

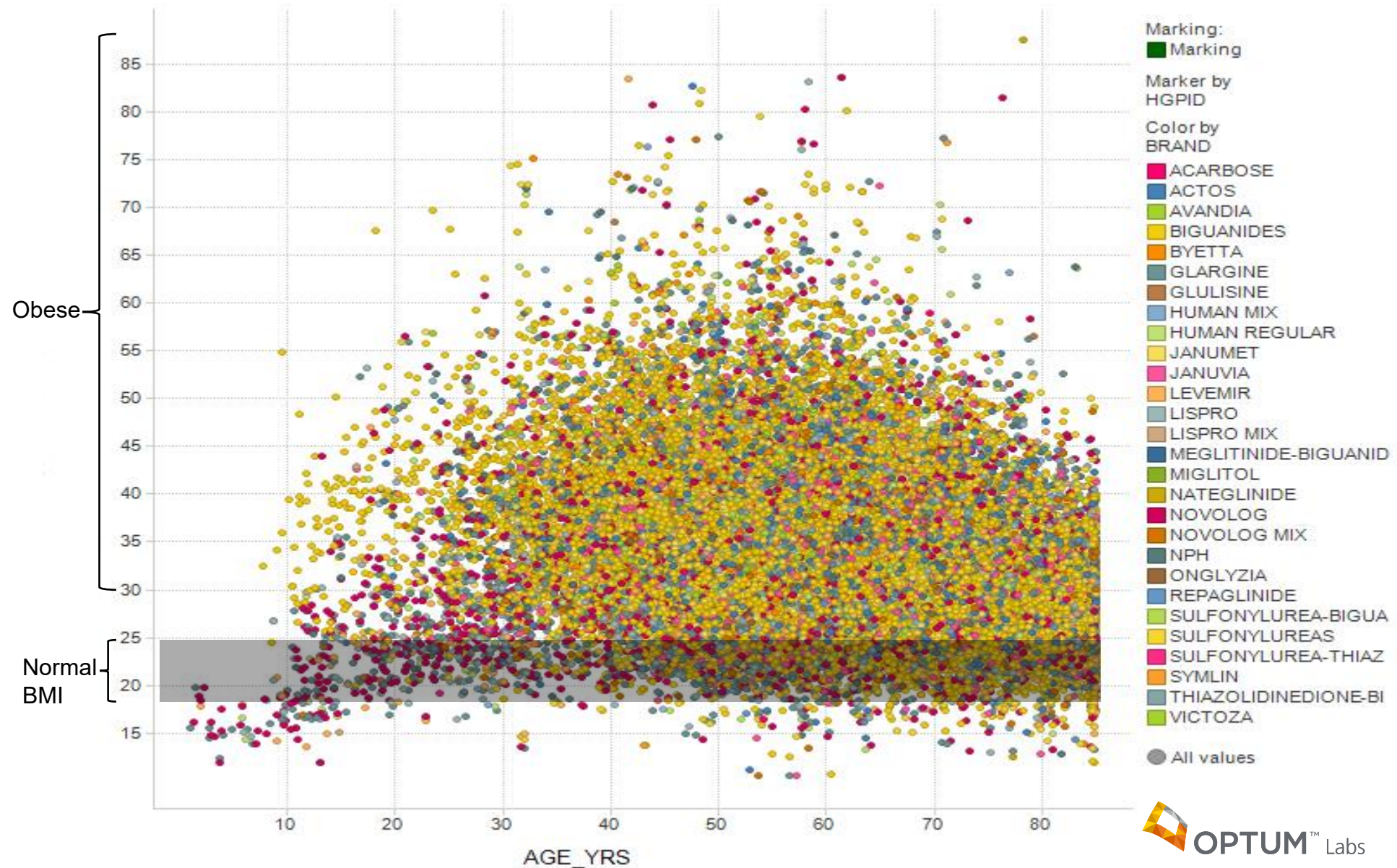
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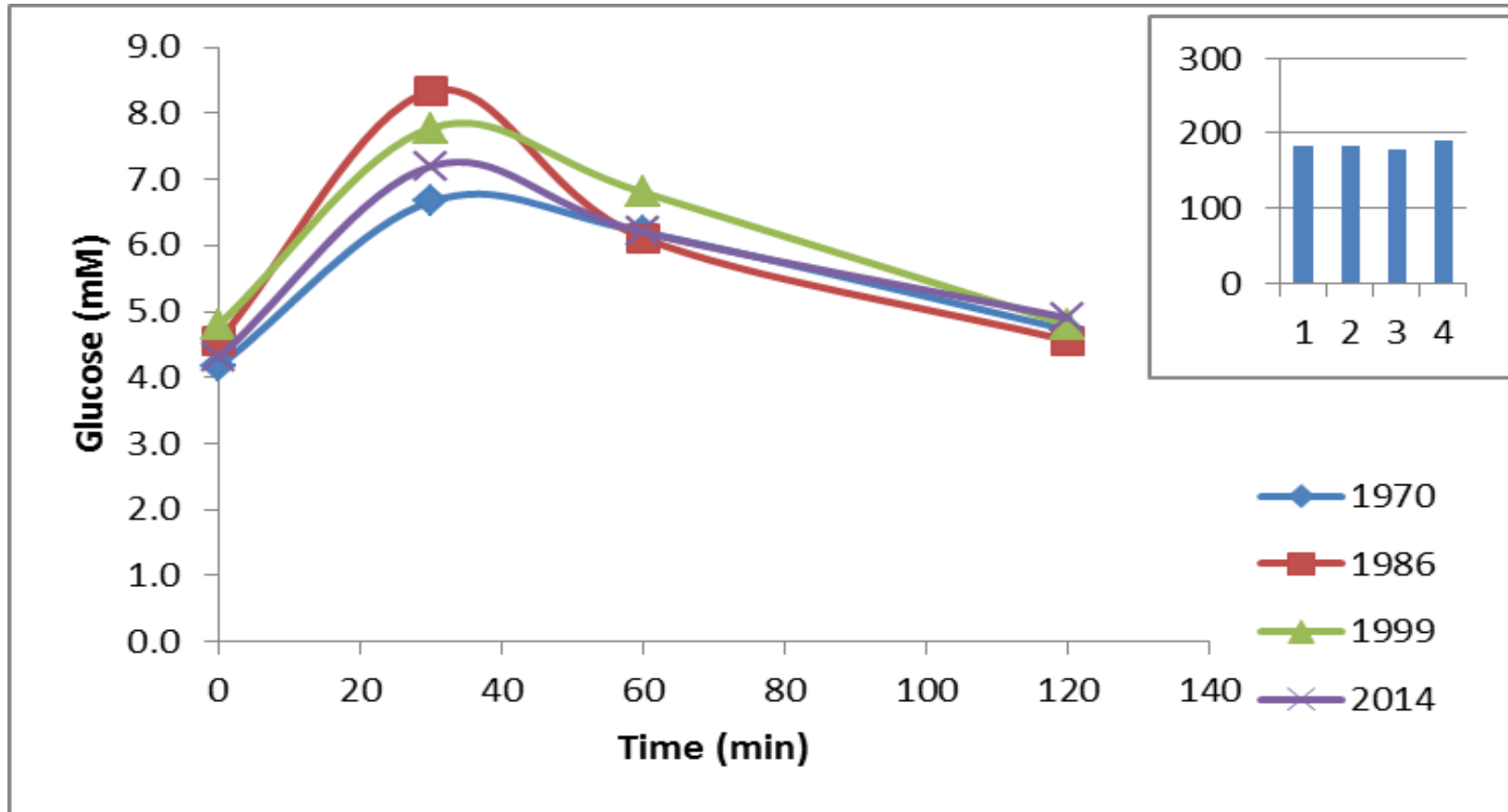
**Scientific Advisor, Levels Health, Austin TX**

**SwissRe, Armonk, NY, Feb 25, 2026**

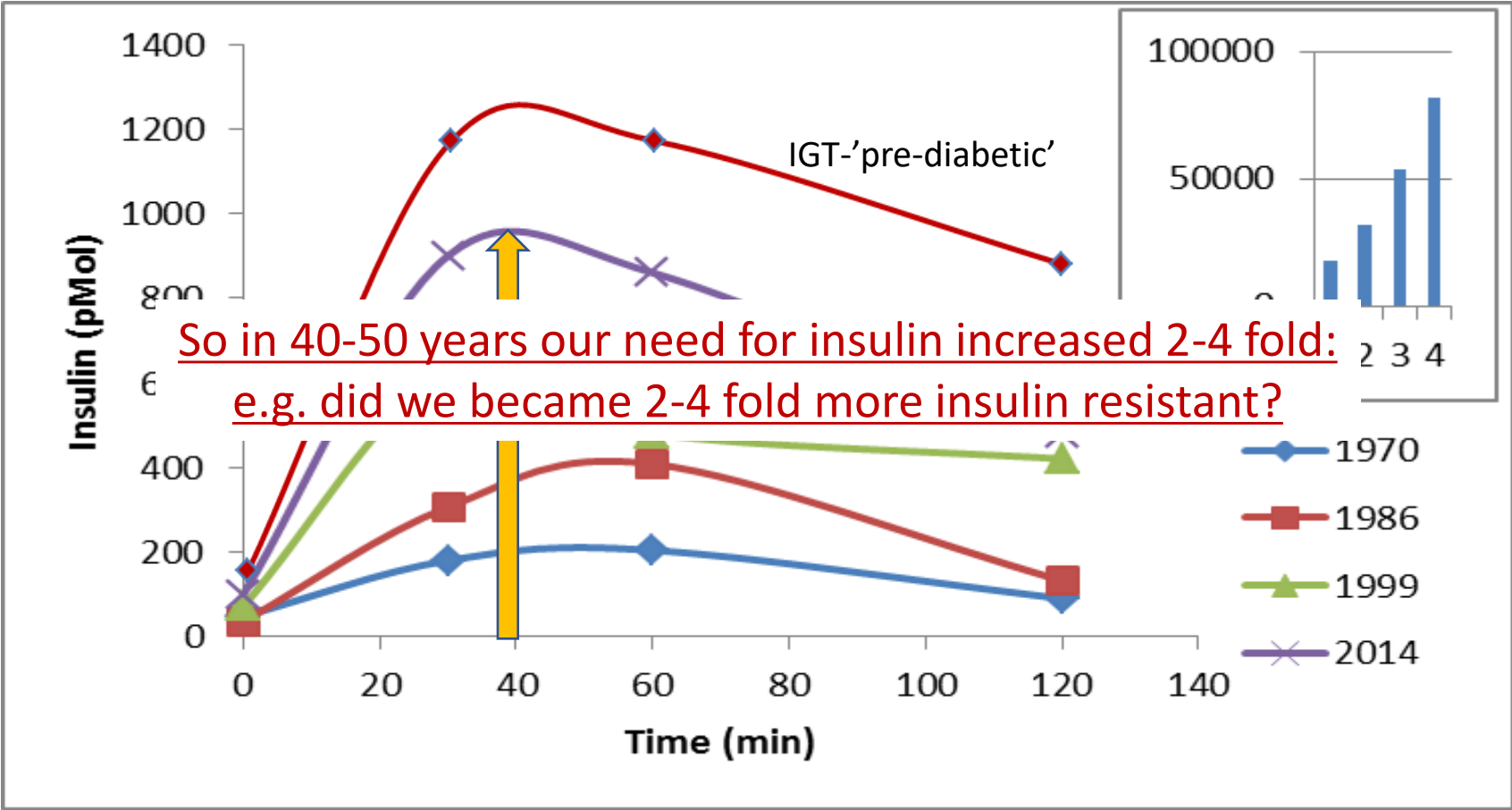
# The complications of obesity are not restricted to the obese, and not restricted to adults



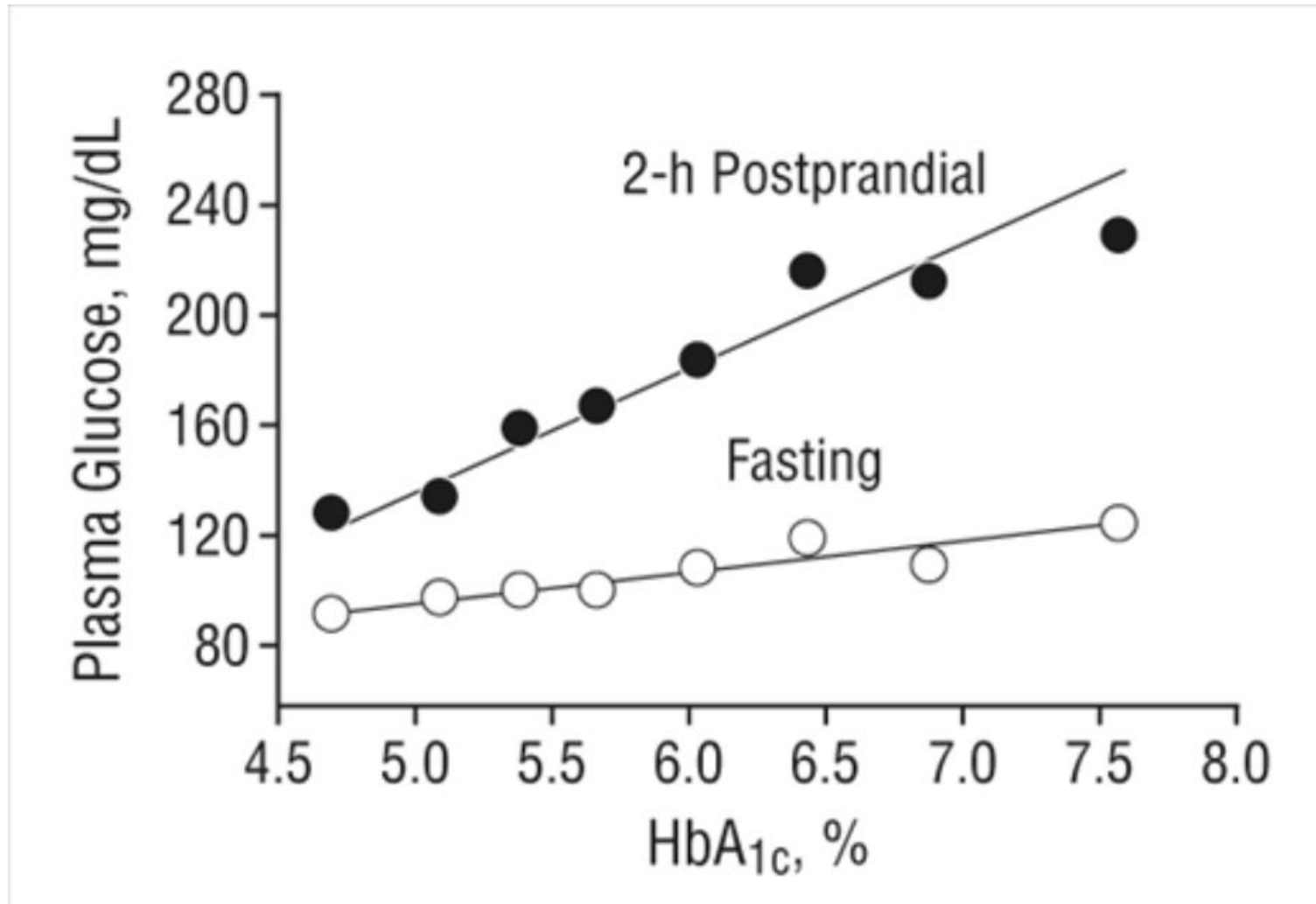
## OGTT in 'healthy' volunteers from ~1970 till 2014



# OGTT in 'healthy' volunteers from ~1970 till 2014



# Even a slight rise in HbA1c predicts altered glucose dynamics

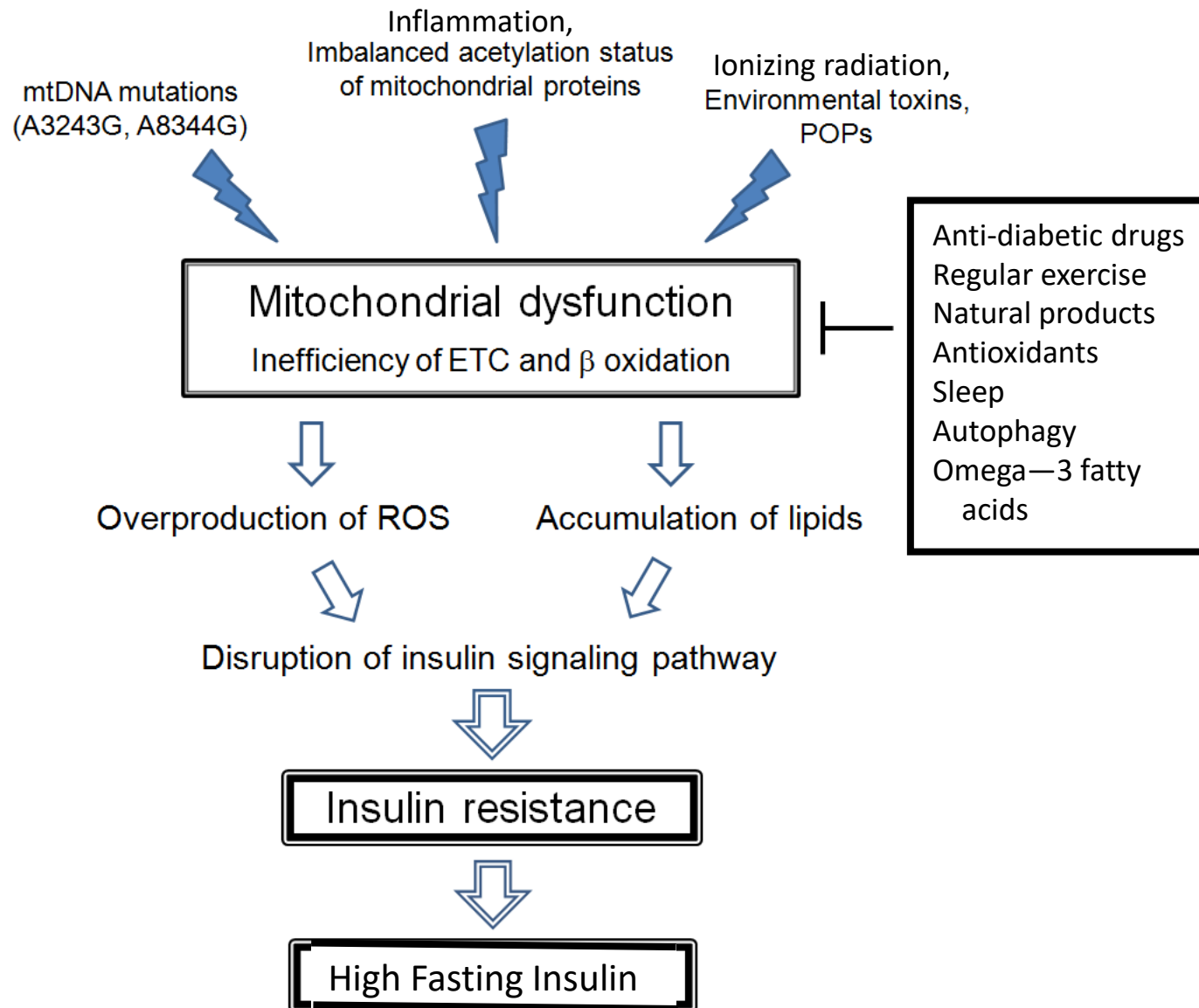


## Even a slight rise in HbA1c predicts earlier mortality

**Table 2** Age adjusted rates for all cause, cardiovascular, ischaemic heart disease, and non-cardiovascular death by glycated haemoglobin concentration and self reported diabetes in men aged 45-79 years, 1995-9

Cause of death	Glycated haemoglobin (%)				Self reported diabetes (n=160)	$\chi^2$ (linear trend), P value
	<5 (n=1204)	5-5.4 (n=1606)	5.5-6.9 (n=1611)	$\geq 7$ (n=81)		
All causes (n=135)						
Age adjusted rate/100 (No of events)	1.65 (18)	2.33 (35)	3.43 (61)	4.35 (5)	5.92 (16)	40.8,
Relative risk	1.00	1.41	2.07	2.64	3.59	<0.001
Cardiovascular disease (n=60)						
Age adjusted rate/100 (No of events)	0.50 (5)	1.27 (19)	1.24 (22)	2.54 (3)	4.11 (11)	31.8,
Relative risk	1.00	2.53	2.46	5.04	8.16	<0.001
Ischaemic heart disease (n=42)						
Age adjusted rate/100 (No of events)	0.31 (3)	0.86 (13)	0.87 (15)	1.63 (2)	3.43 (9)	29.0,
Relative risk	1.00	2.74	2.77	5.20	10.91	<0.001
Non-cardiovascular disease (n=75)						
Age adjusted rate/100 (No of events)	1.15 (13)	1.06 (16)	2.19 (39)	1.81 (2)	1.82 (5)	11.8,
Relative risk	1.00	0.92	1.91	1.58	1.58	<0.001

# Fasting hyperinsulinemia is the closest surrogate biomarker of mitochondrial dysfunction



# Fasting insulin is the most convenient surrogate measure

There is no direct marker of mitochondrial function

**Fasting glucose** is the last thing to change

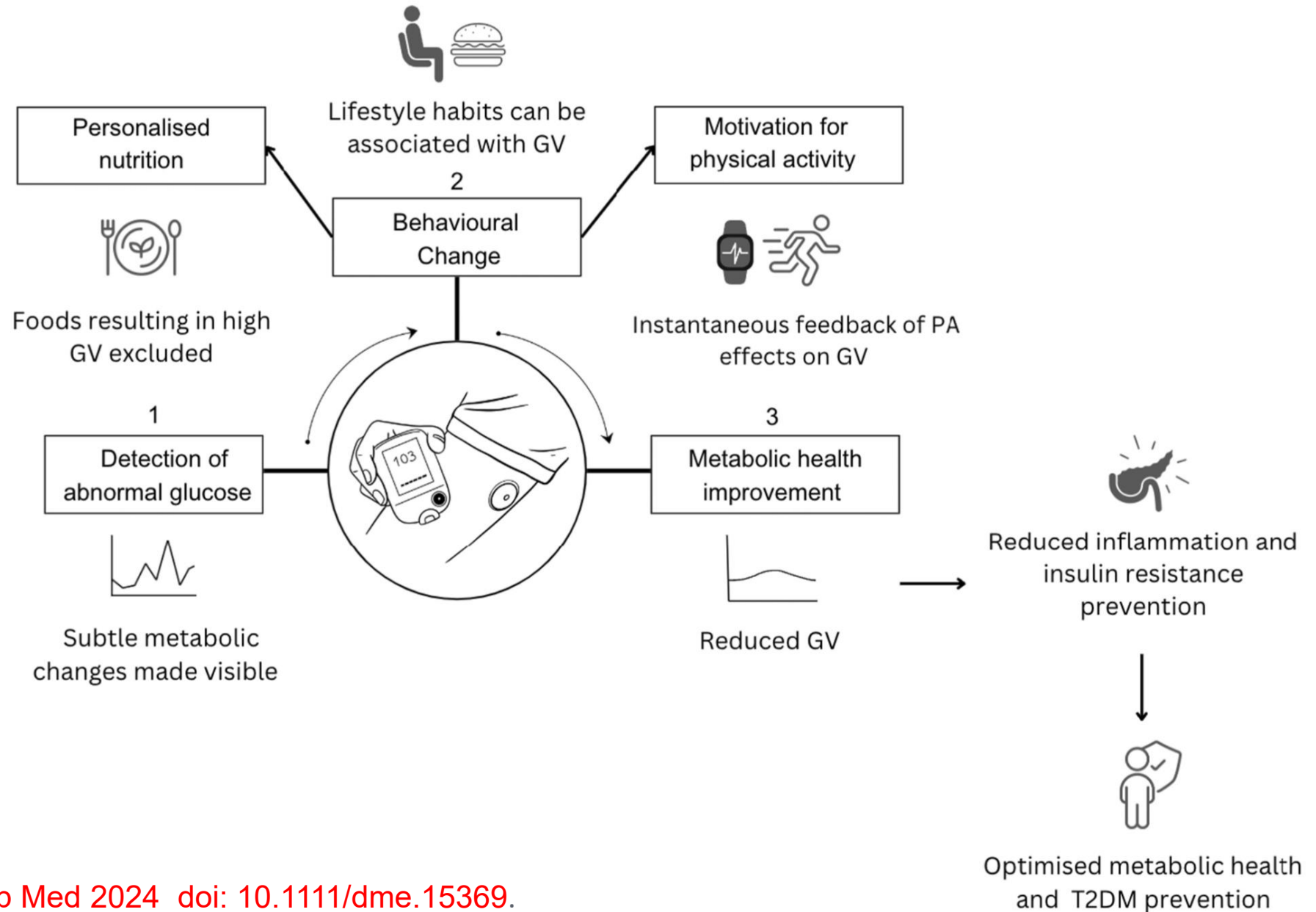
**HbA1c** is the second to last thing to change

But **fasting insulin** is the first thing to change

Also **post-prandial glucose** can provide information

What else can provide information about that? **CGM's?**

# Continuous Glucose Monitors



# Do CGM's work? And how?

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DIABETIC  
Medicine

## REVIEW

# Innovative solution or cause for concern? The use of continuous glucose monitors in people not living with diabetes: A narrative review

Zhanna Oganeseva<sup>1</sup> | John Pemberton<sup>2</sup> | Adrian Brown<sup>1,3,4</sup> 

**TABLE 2** CGM measures for people not living with diabetes (PNLD), at risk for type II diabetes, with prediabetes and with type II diabetes.

CGM measure	User cohort				ATTD target values T1/2DM (%)
	PNLD	At risk for T2DM	Prediabetes	T2DM	
TIR (3.9–10.0 mmol/L)	97.3 [95.4, 98.7]	98.0** [95.6, 99.4]	97.8** [95.8, 98.7]	85.6** [67.7, 91.6]	>70
TBR (<3.9 mmol/L)	1.6 [0.6, 3.2]	2.0* [0.3, 4.4]	1.6* [0.5, 4.0]	0.2* [0, 1.1]	<4
TAR (>10.0 mmol/L)	0.25 [0, 1.29]	0** [0, 0]	0.2** [0, 0.6]	11.4** [4.6, 28.6]	<25
GV (%CoV)	20	16.0** [13.1, 18.4]	17.7** [15.6, 20.3]	23.2** [20.2, 27.9]	≤36

**Results:** We find a lack of consistent and high-quality evidence to support the utility of CGMs for these purposes. We identify significantly under-reserved areas including clinical benchmarks and scoring procedures for CGM measures, device acceptability, and potential adverse effects of CGMs on eating habits in PNLD. We also raise concerns about the robustness of available CGM research.

# Continuous Glucose Monitors Should Not Be Normalized

Boris Hansel, MD

The Observer Nutrition

## 'Personalising stuff that doesn't matter': the trouble with the Zoe nutrition app

The wellness project claims to help users make 'smarter food choices' based on 'world-leading science'. But many scientists claim its fee-based services are no better than generic advice

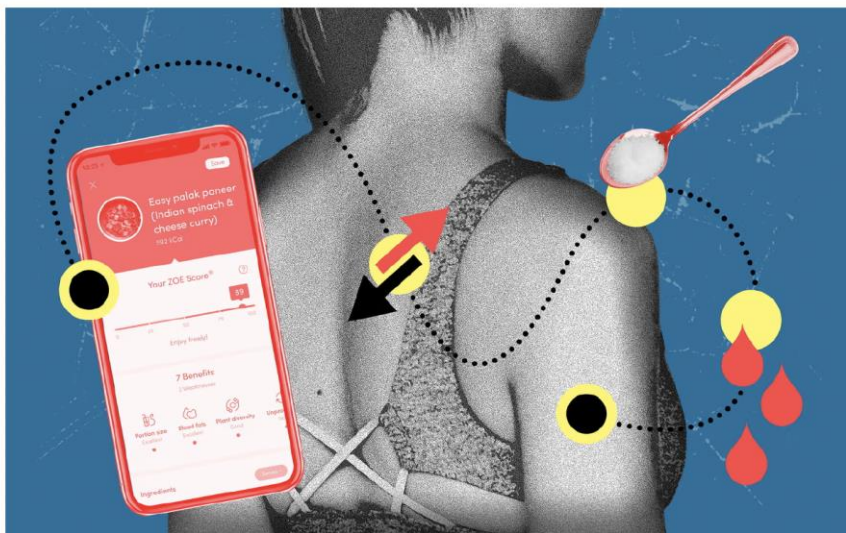


Illustration by Observer Design.



Julian Baggini

Sat 18 May 2024 13.00 BST

BBC

# Going down the 'rabbit hole' of wearable blood-sugar monitors

9 hours ago

By Holly Honderich, BBC News

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Getty Images

Continuous glucose monitors have become powerful tools for those living with diabetes

**Blood-sugar monitoring devices could soon be on the arms of millions of Americans after regulators cleared two new devices for use without a prescription. Is it a way to improve our health? Or is the data just another distraction?**

# Doctors question science behind blood sugar diet trend

15 March 2024

By Rachel Schraer, Health and disinformation reporter

BBC

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# Is blood sugar monitoring without diabetes worthwhile?

April 23, 2024



By **Robert H. Shmerling, MD**, Senior Faculty Editor, Harvard Health Publishing; Editorial Advisory Board Member, Harvard Health Publishing

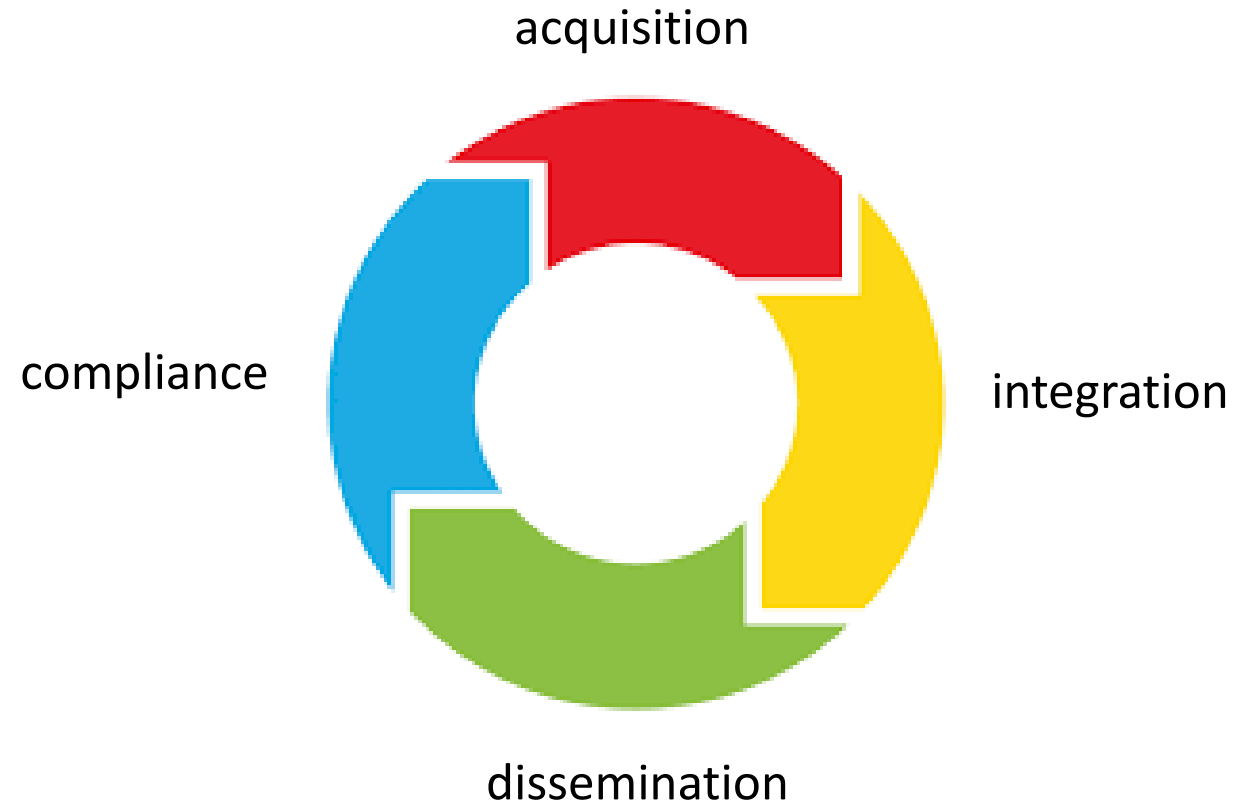


But truly, knowledge that is useless, redundant, or inaccurate doesn't make you powerful! It may even be harmful. For example, if biologically insignificant drops in blood sugar lead you to snack more ("to avoid hypoglycemia"), you could gain weight and actually *increase* your risk of developing diabetes. If the monitoring system sometimes provides inaccurate information or false alarms, unnecessary anxiety, calls or visits to the doctor, visits to an emergency room, and even inappropriate treatment may follow.

Unfortunately, some makers of CGM systems aren't waiting for solid research results to market these devices to healthy people. So, consumers and marketing professionals – not researchers or doctors – may wind up driving demand for the product. For any new technology there's a scientific learning curve to figure out when to use it. In my view, we're at the very beginning of the learning curve for home monitoring of blood sugar in people without diabetes. Before buying into what may be the next fad in health monitoring, I think we need to learn a lot more.

There is wisdom in the teachings of one of my favorite professors in medical school: "Just because you *can* measure something doesn't mean you *should*."

# CGM — Can an iterative paradigm change individual or collective behavior?



# LEVELS

## Understand how food affects your health

- 93% of Americans are not metabolically healthy. Levels mission is to **reverse the metabolic health crisis**
- Levels provides **real-time biofeedback** on diet and lifestyle via continuous glucose monitors (CGM), paired with access to metabolic blood work, intelligent software, and in-depth metabolic education
- Levels has amassed the **largest dataset of it's kind**, over 700M glucose data points paired with food logs - poised to transform the nutrition industry
- Advisor board includes key global metabolic thought leaders, including Drs. David Sinclair, Mark Hyman, Rob Lustig, David Perlmutter, Terry Wahls, Sara Gottfried, and more



**Iterative, not static**  
**Community, not individual**



# CGM – personal data capture and societal data capture

## Food

### **Spike <20 mg/dl avg <100 mg/dl::**

- Eggs
- Coffee: black, bulletproof, with or without cream
- Keto desserts
- Meats: chicken, sausage, turkey, bacon, steak, salmon, tuna, ham
- Avocado
- Cottage cheese
- Sauerkraut
- Greek yogurt
- Nuts: raw, mixed, peanuts, peanut butter

### **Spike >50 mg/dl:**

- Panera sandwich
- Cheese burger
- Prolon Soups
- Licorice, Skittles, Twizzlers
- Oat Milk Cappuccino
- Oatmeal, Rice, Couscous
- Yam
- Coffee Cake
- Macrobars
- Ramen
- Chicken Tender
- Enchilada,
- French Fries
- Dim Sum

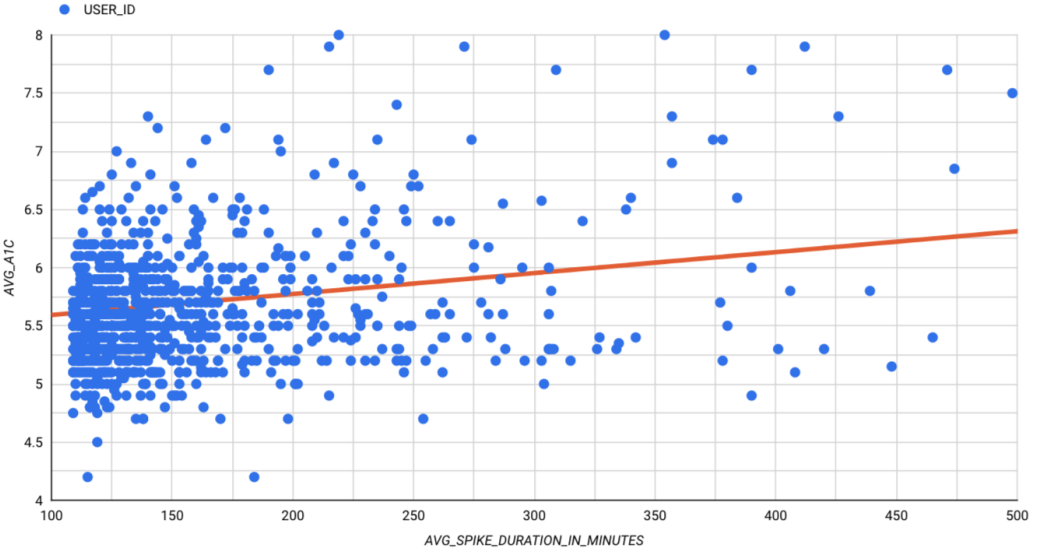
### **Spike > 50, avg >110 mg/dl:**

- Candies (Skittles, Tootsie Pop, Twizzlers)
- Wendys, Burger King
- Beef pho
- Ramen Noodle
- Thai fried rice
- Frosted Mini-Wheats
- Thai Iced Tea
- Tofu and Rice
- Popcorn
- Spring rolls
- Udon Noodles
- Waffles and Syrup

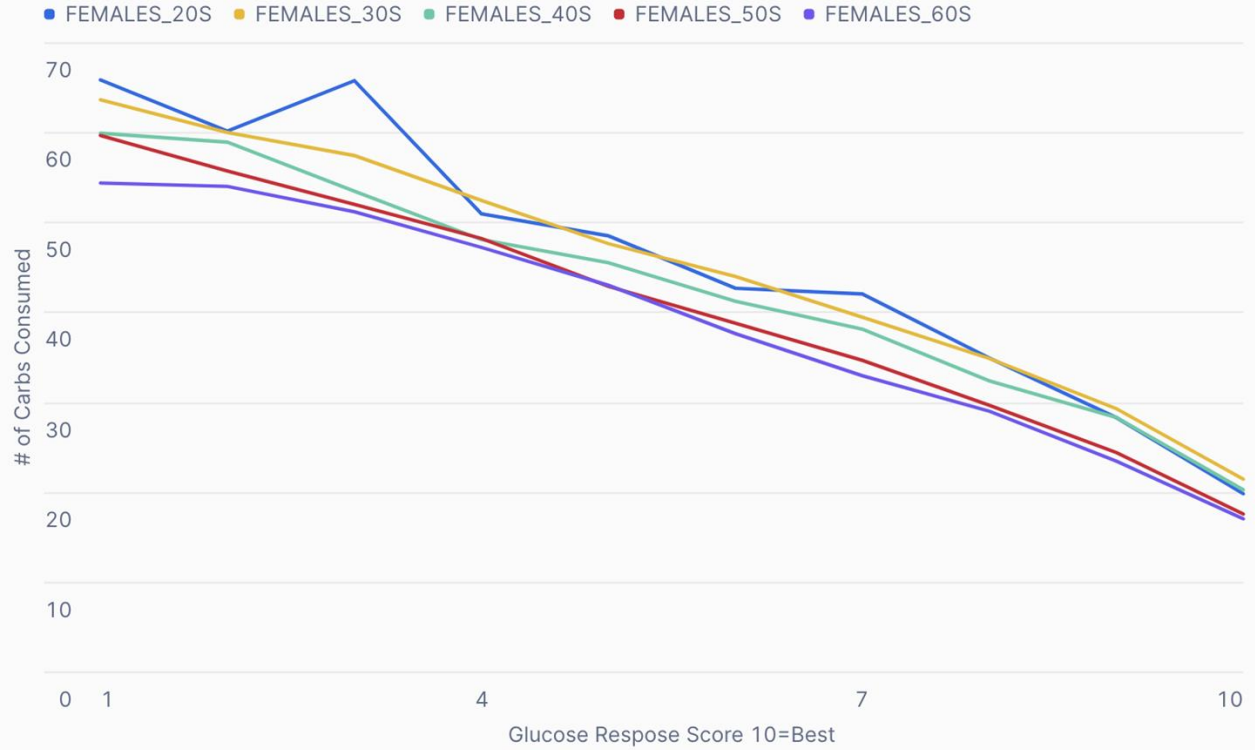
# CGM – personal data capture and societal data capture

## Dietary Choices

### A1C correlates w/ Spikes Length

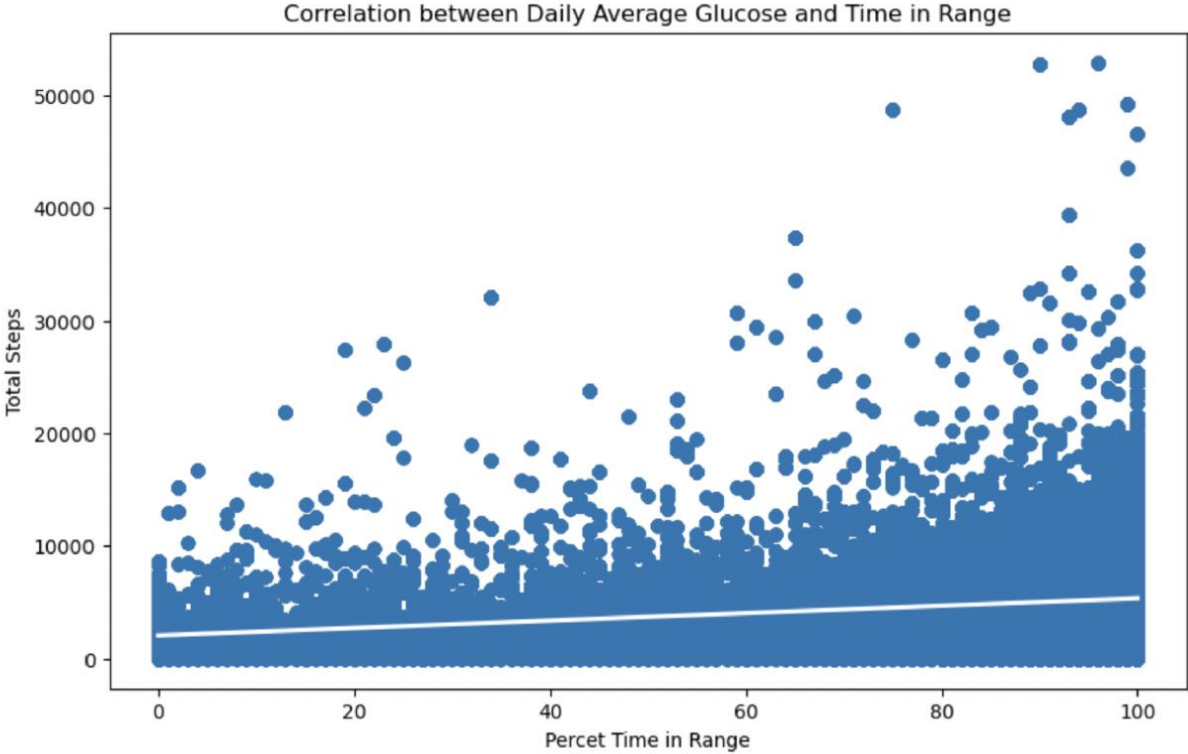
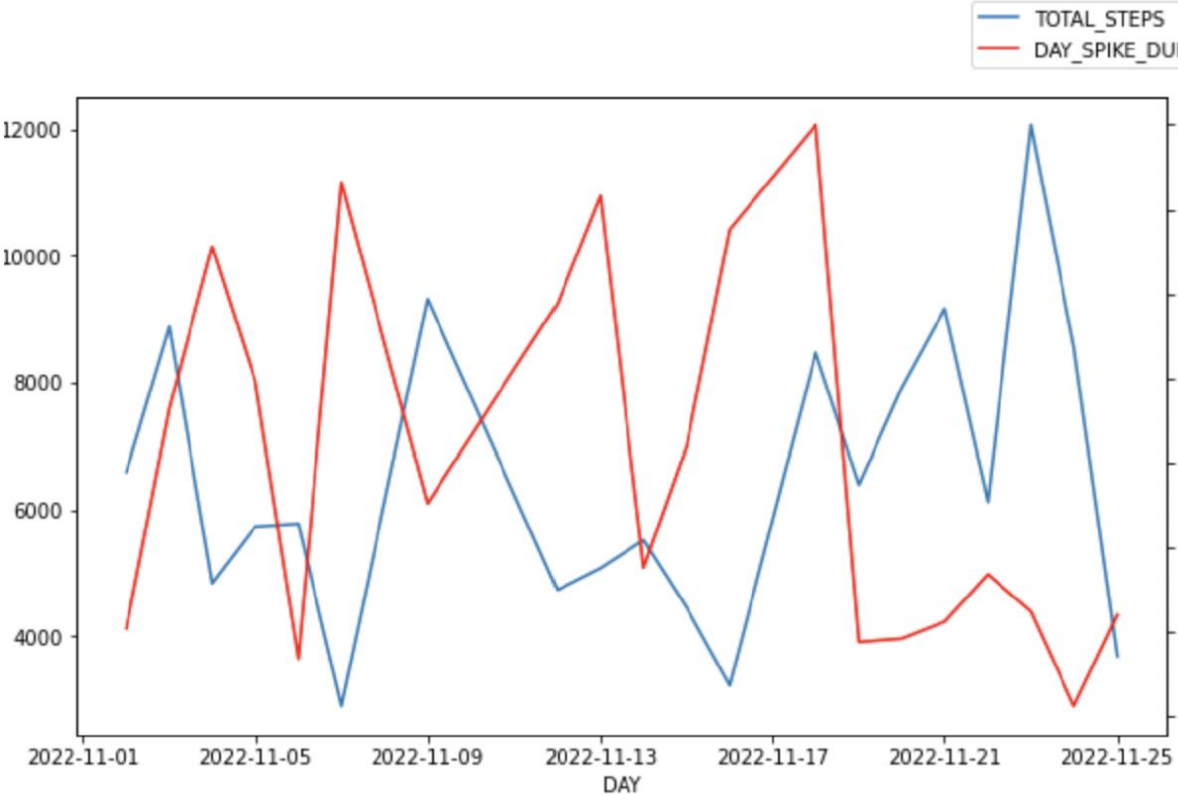


### Age Categorized Carb Tolerance



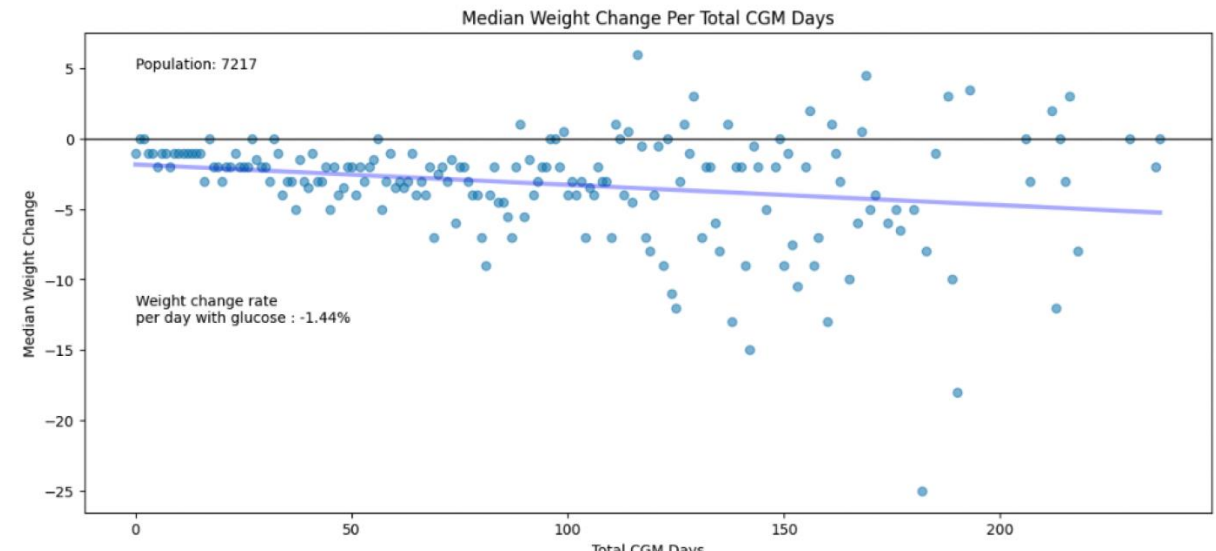
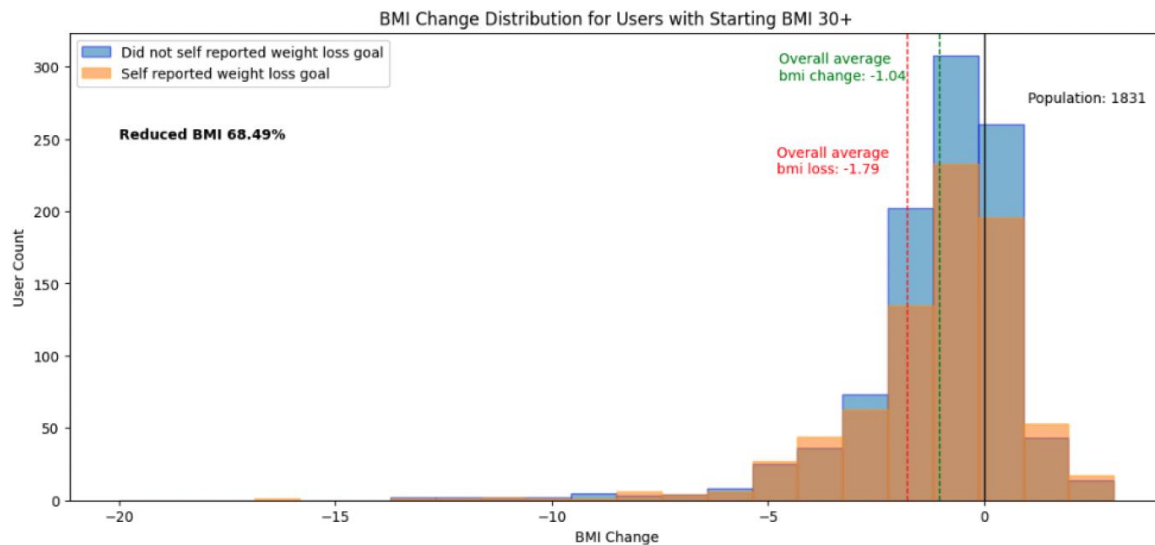
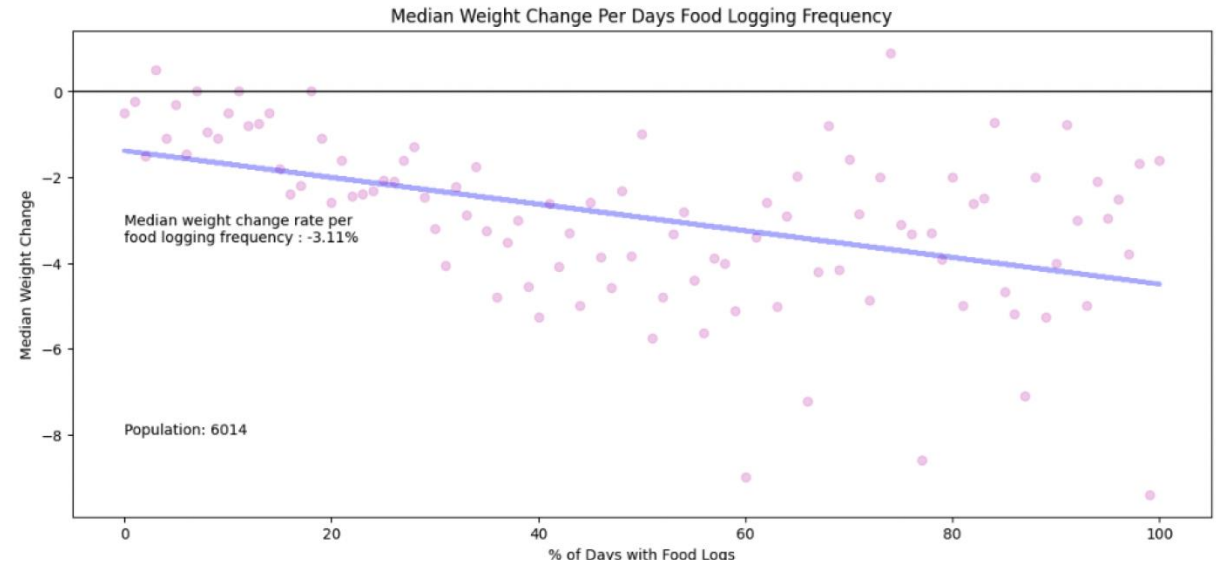
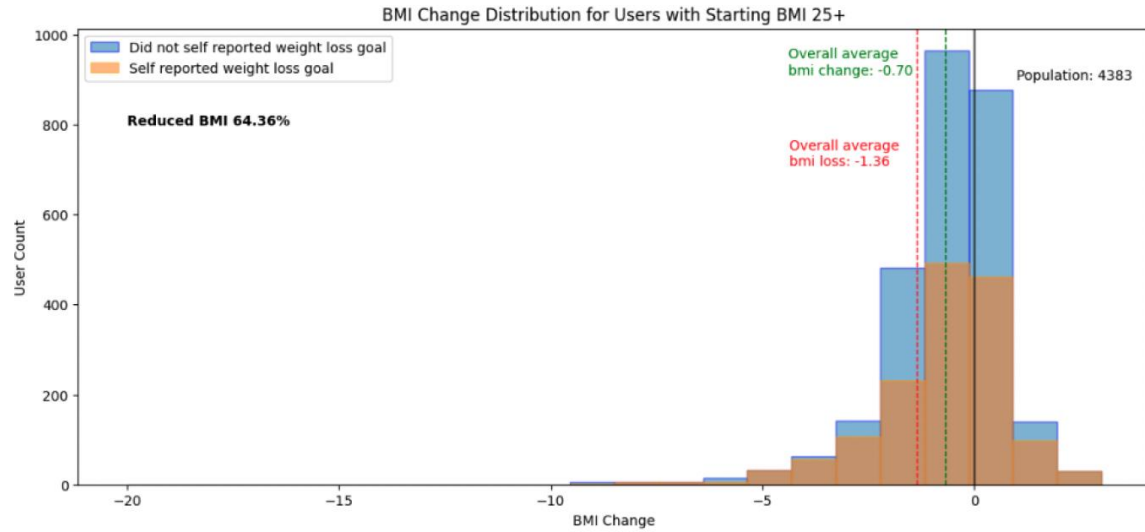
# CGM – personal data capture and societal data capture

## Exercise



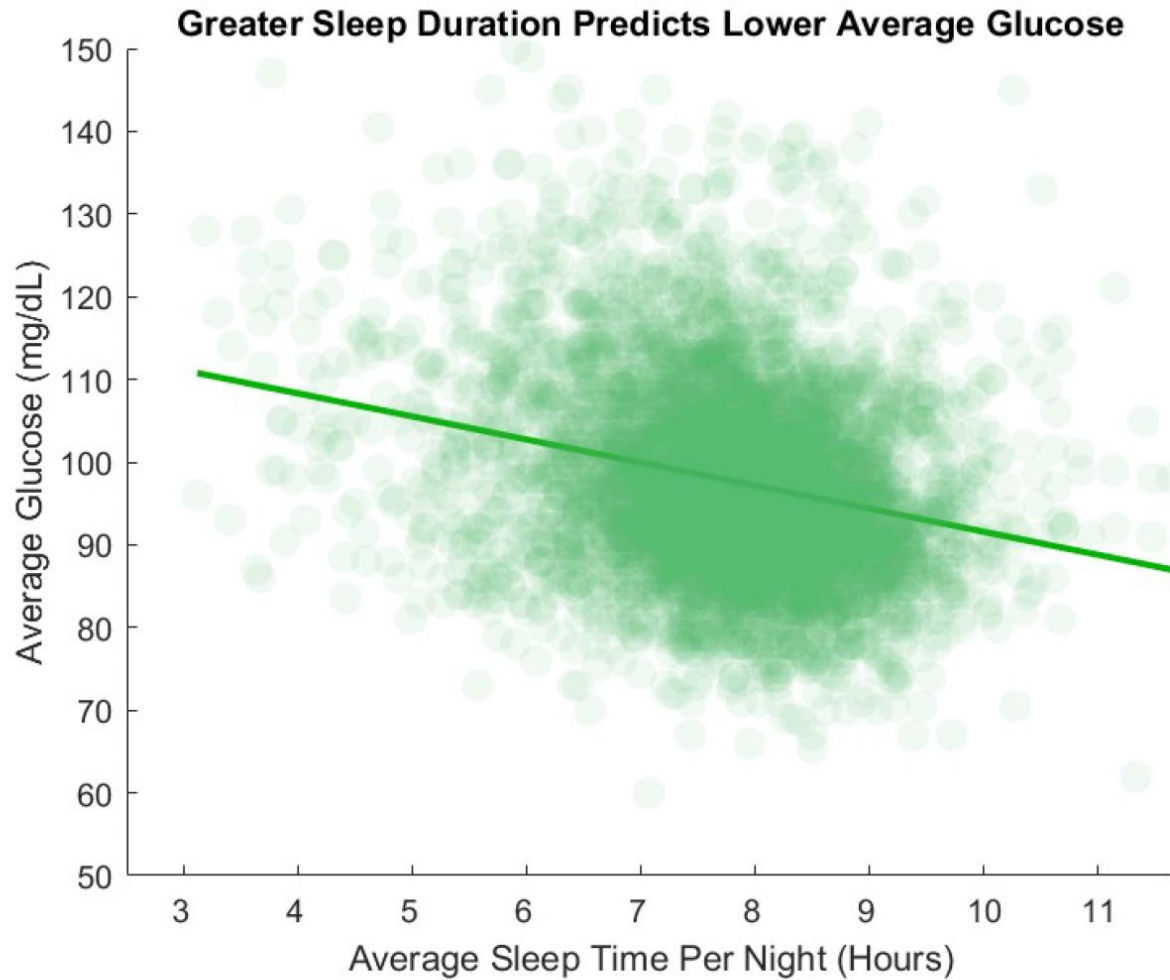
# CGM – personal data capture and societal data capture

## Weight loss

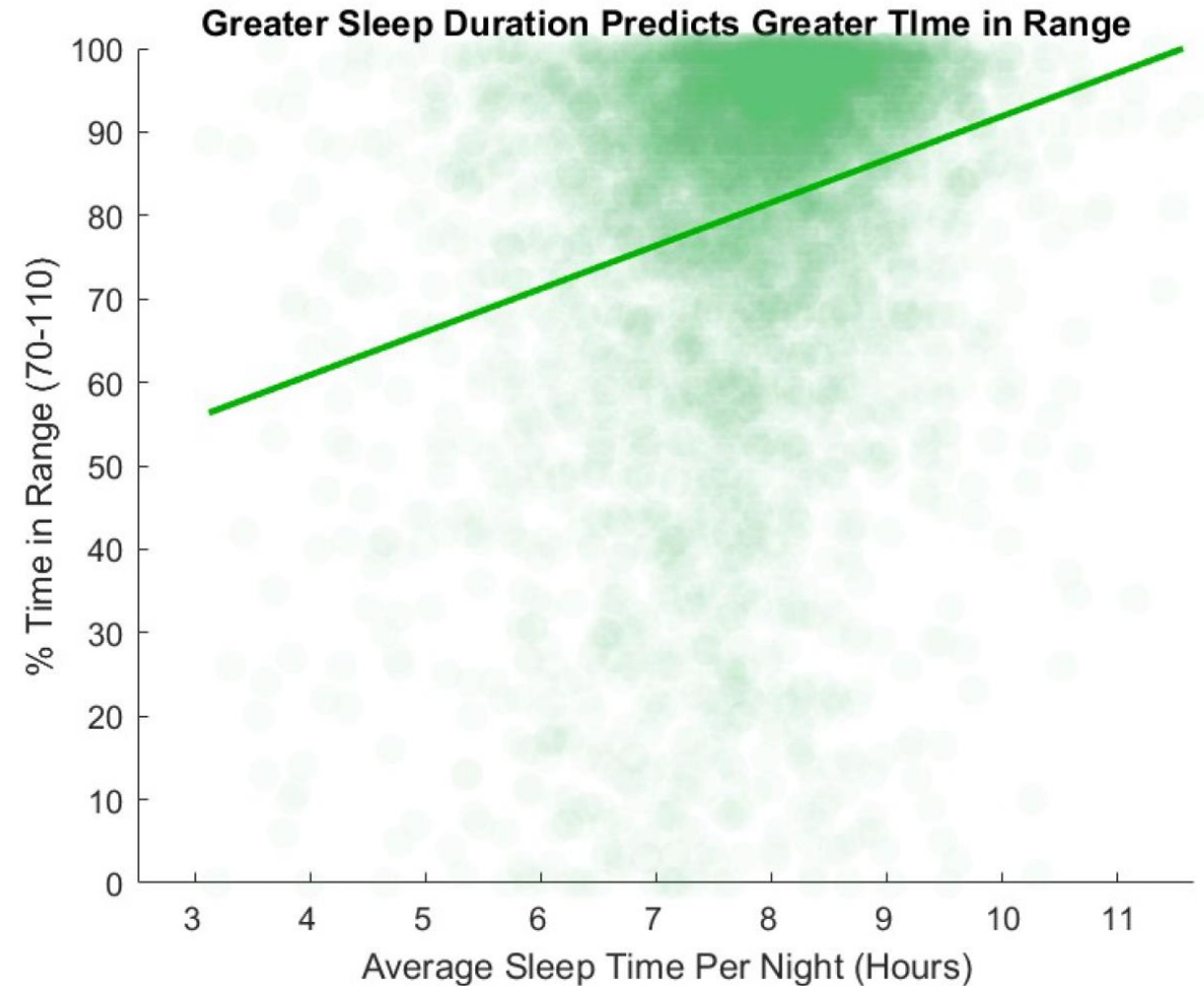


# CGM – personal data capture and societal data capture

## Sleep



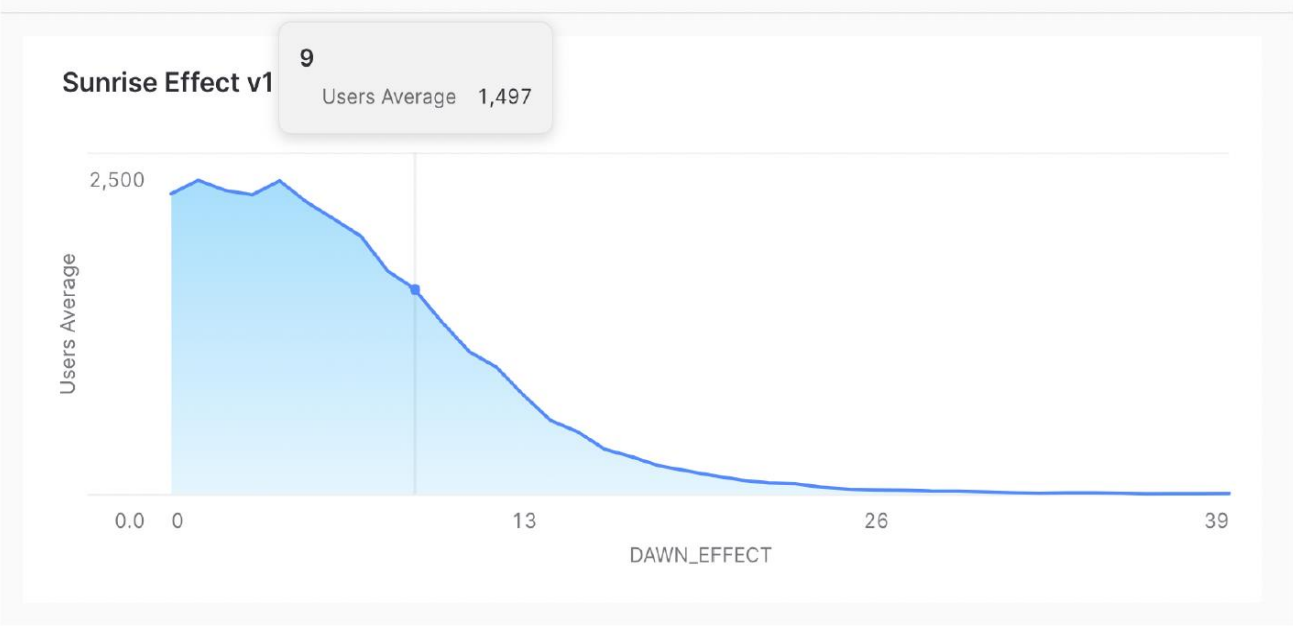
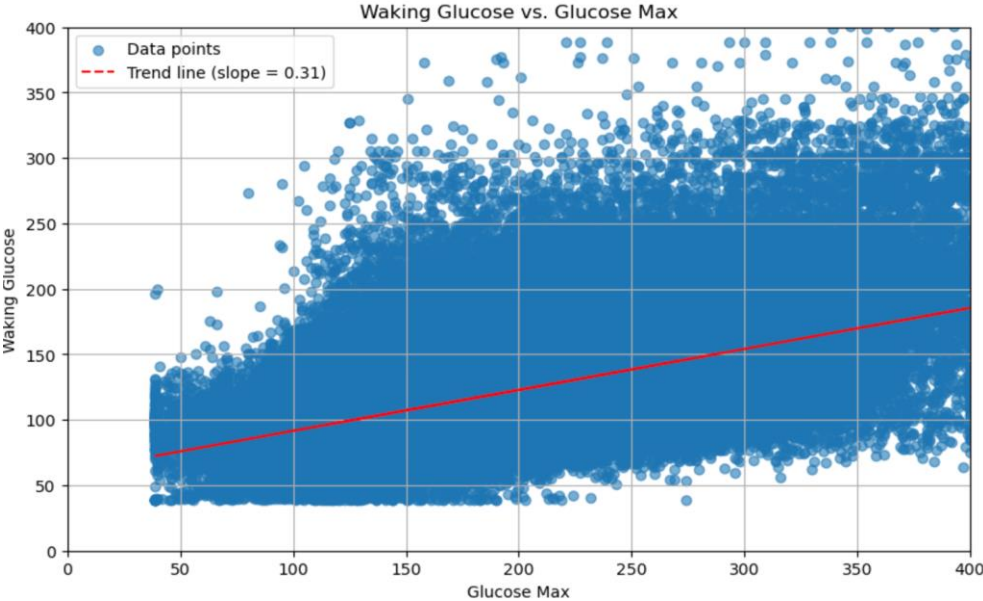
Avg Corcoef=-0.23, rsq 0.05 p 1.65e-60. Weak but statistical LM.



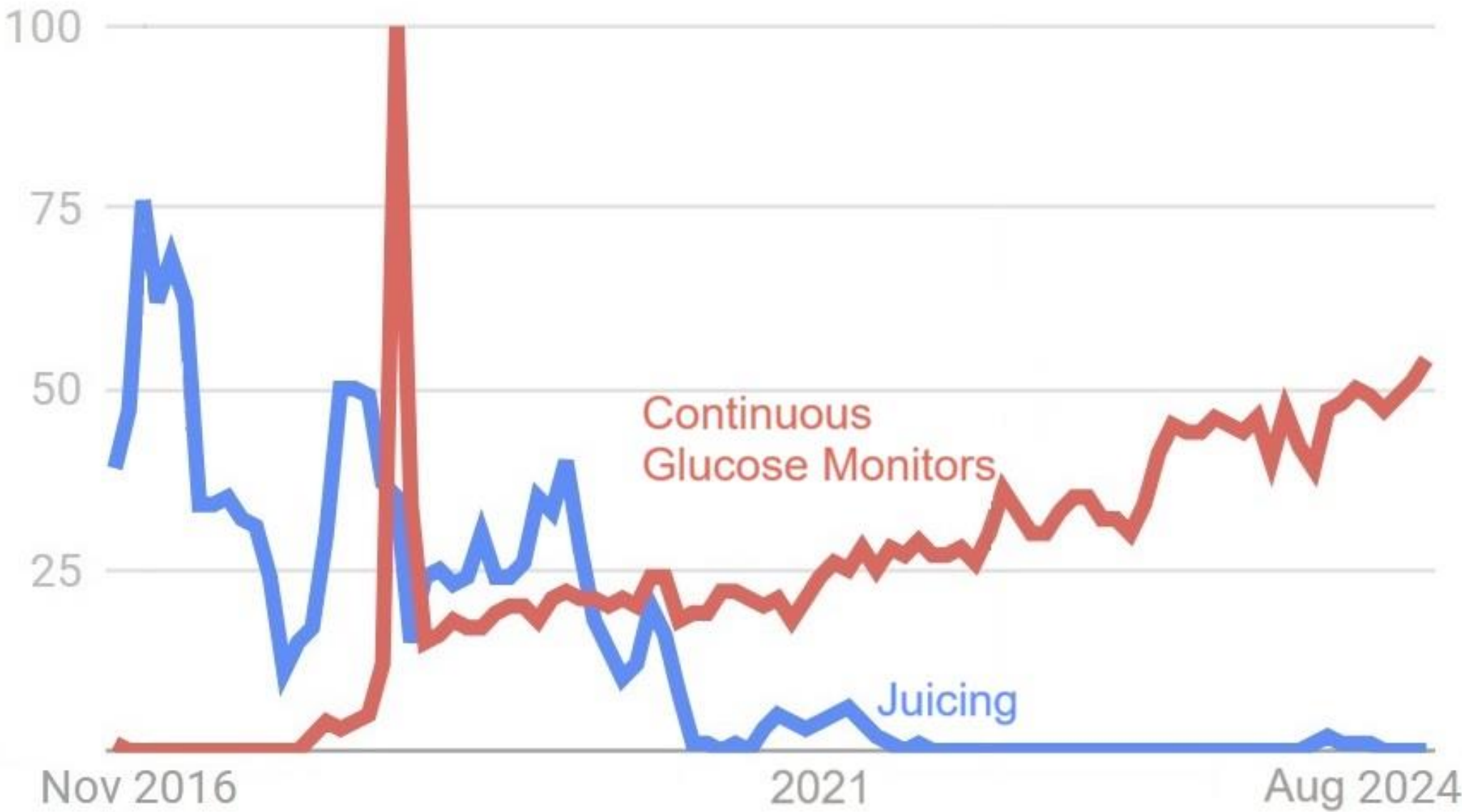
Avg Corcoef = 0.26 rsq 0.06 p 2.51e-69

# CGM – personal data capture and societal data capture

## Sleep



# Google Trends: Interest in Juicing and Continuous Glucose Monitors



# Summary

- To develop a diagnostic, you have to know what you're looking for.
- In nutrition, that may be hard, but remember the goal is METABOLIC HEALTH.
- Diabetes is the end-stage problem, we're looking for the first-stage problem.
- The problem is in the mitochondria, but we don't have good biomarkers.
- The next best thing is fasting insulin.
- Post-prandial hyperglycemia is also good, but only if you can do something about it.
- CGM's provide glucose information, which is a proxy for insulin information.
- CGM's are the Hawthorne Effect – by observing an event you change it.
- Food logging is even better than CGM.