



In the Range: Real Talk on Diabetes Monitoring Best Practices

Episode 1: DKA in Focus: What the New Consensus Means for Practice

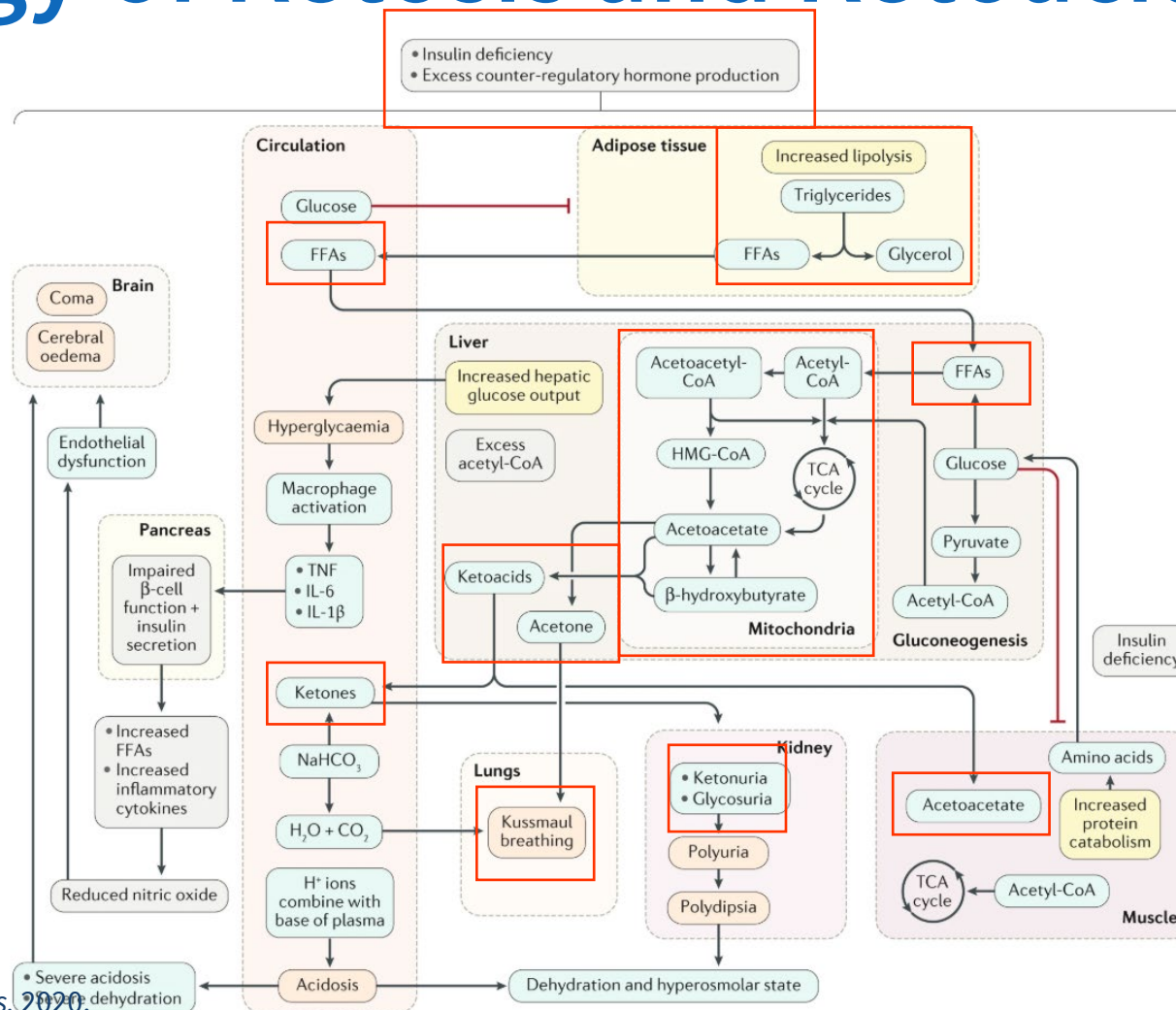


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Physiology of Ketosis and Ketoacidosis



Dhatariya K, et al. *Nat Rev Dis Primers*. 2020.

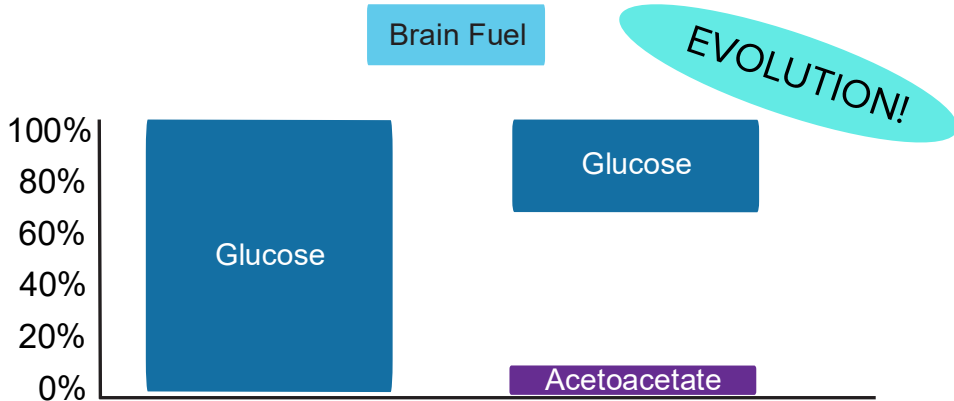
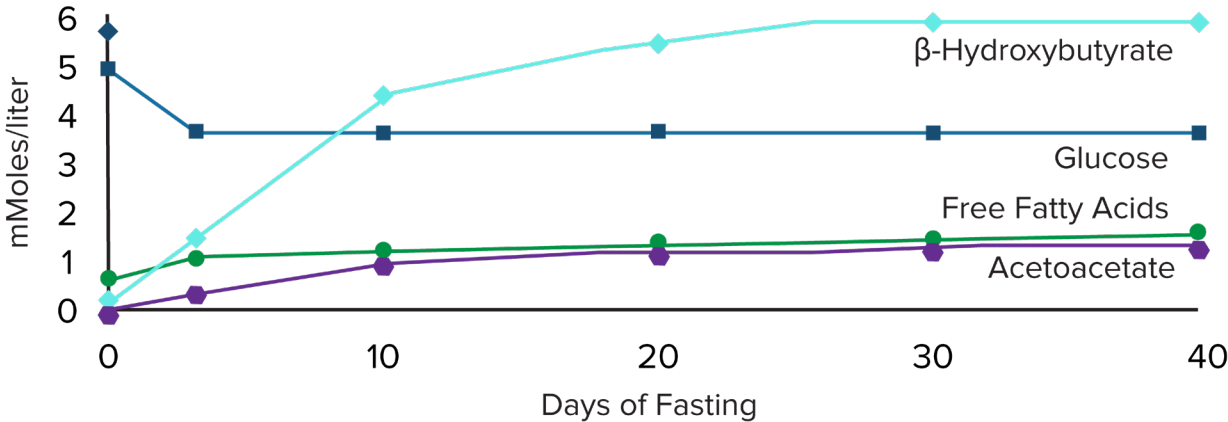


Ketones – Why Are They Important?

Levels of Circulating Substrates

Period of Observation	β -Hydroxybutyrate mM	Free Fatty Acids	Acetoacetate	Glucose mg/100 ml	Glycerol	Amino Acids	Lactate	Pyruvate
Post absorptive	0.01	0.5	0.01	80	0.06	4.5	0.6	0.1
After 1 week fast	4.0	1.5	1.0	65	0.1	4.5	0.6	0.1
After 4-5 week fast	6.0	1.5	1.5	65	0.1	3.5	0.6	0.1

Blood Glucose, Free Fatty Acids and Ketone Body Levels During Fast



Cahill GF. *NEJM*. 1970; Cahill GF. *Diabetes* 1971; Cahill GF. *Ann Rev Nutr*. 2006.

Living Longer on Starvation Diets



A Ketogenic Diet Extends Longevity and Healthspan in Adult Mice

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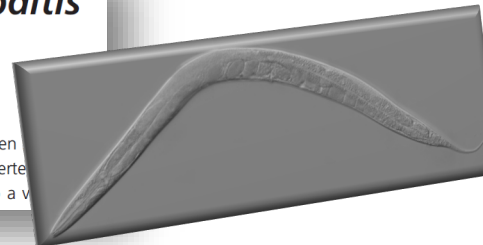
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<http://dx.doi.org/10.1016/j.cmet.2017.08.005>



Dietary deprivation extends lifespan in *Caenorhabditis elegans*

Garrick D. Lee,¹ Mark A. Wilson,² Min Zhu,¹ Catherine A. Wolkow,² Rafael de Cabo,¹ Donald K. Ingram^{1,3} and Sige Zou¹

dietary restriction (DR) (Masoro, 2005). DR has been shown to extend lifespan in many species, ranging from invertebrates to mammals. In addition, DR enhances resistance to a variety of stressors.



LETTER

doi:10.1038/nature11432

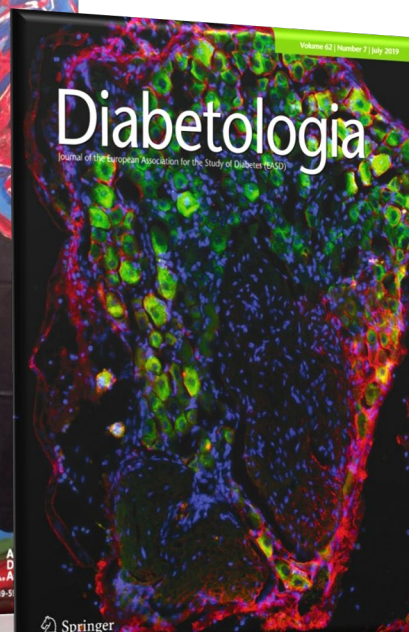
Impact of caloric restriction on health and survival in rhesus monkeys from the NIA study

Julie A. Mattison¹, George S. Roth², T. Mark Beasley³, Edward J. Rabinowitz⁴, David B. Allison⁵, Jennifer E. Van Vleet⁶, Jennifer E. Seeman⁷, & Rafael de Cabo¹



Lee GD, et al. *Ageing Cell*. 2006; Roberts MN, et al. *Cell Metabol*. 2017; Mattison JA, et al. *Nature*. 2012.

Consensus Report: Published August 2024



CONSENSUS REPORT

Hyperglycaemic crises in adults with diabetes: a consensus report

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Umpierrez GE, et al. *Diabetes Care*. 2024; Umpierrez GE, et al. *Diabetologia*. 2024.



New DKA Diagnostic Criteria

DKA	D iabetes/hyperglycaemia	Glucose ≥ 200 mg/dl (11.1 mmol/l) or prior history of diabetes
	K etosis	β -hydroxybutyrate ≥ 3.0 mmol/l or urine ketone strip 2+ or greater
	Metabolic A cidosis	pH < 7.3 and/or bicarbonate concentration < 18 mmol/l

Umpierrez GE, et al. *Diabetes Care*. 2024; Umpierrez GE, et al. *Diabetologia*. 2024.



Physiological vs Pathological

- It's the rate of appearance and the ability for renal and respiratory compensation for the drop in pH
- A rise of β hydroxybutyrate of $\geq 0.2 \text{ mmol/l/hr}$ might be considered 'pathological'
- But there are currently no technologies available to allow prediction or prevention other than glucose meters that say 'Hi' and 'Check ketones' or point of care capillary ketone meters

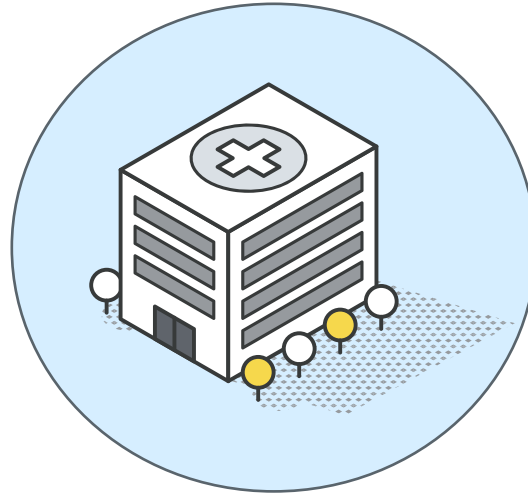
Any Age and Any Kind of Diabetes



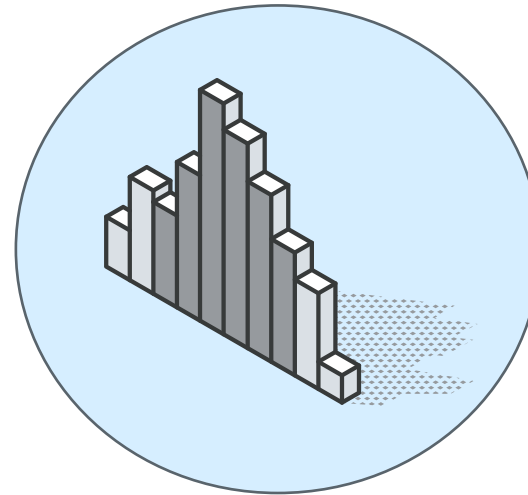
DKA and T2D



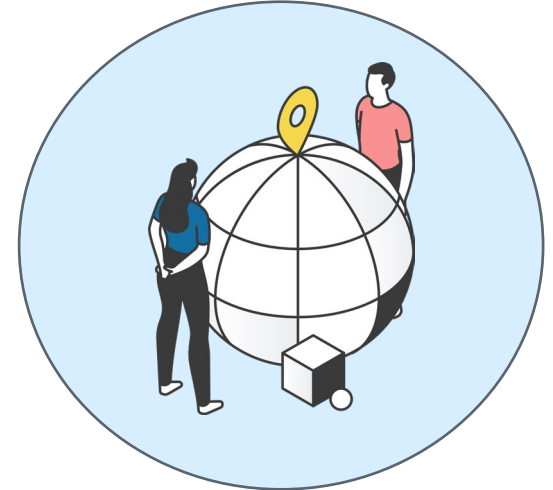
Most common
hyperglycemic
emergency in
persons living with
diabetes



DKA is a leading
cause of death
among children and
adults
(< 58) with diabetes



1%–13% annual
prevalence of DKA
in adults with T1D
across countries



Hospitalization for
DKA: 1 in 5 cases
attributed to T2D



Higher mortality for
T2D (0.85%) with DKA
than T1D (0.2%)

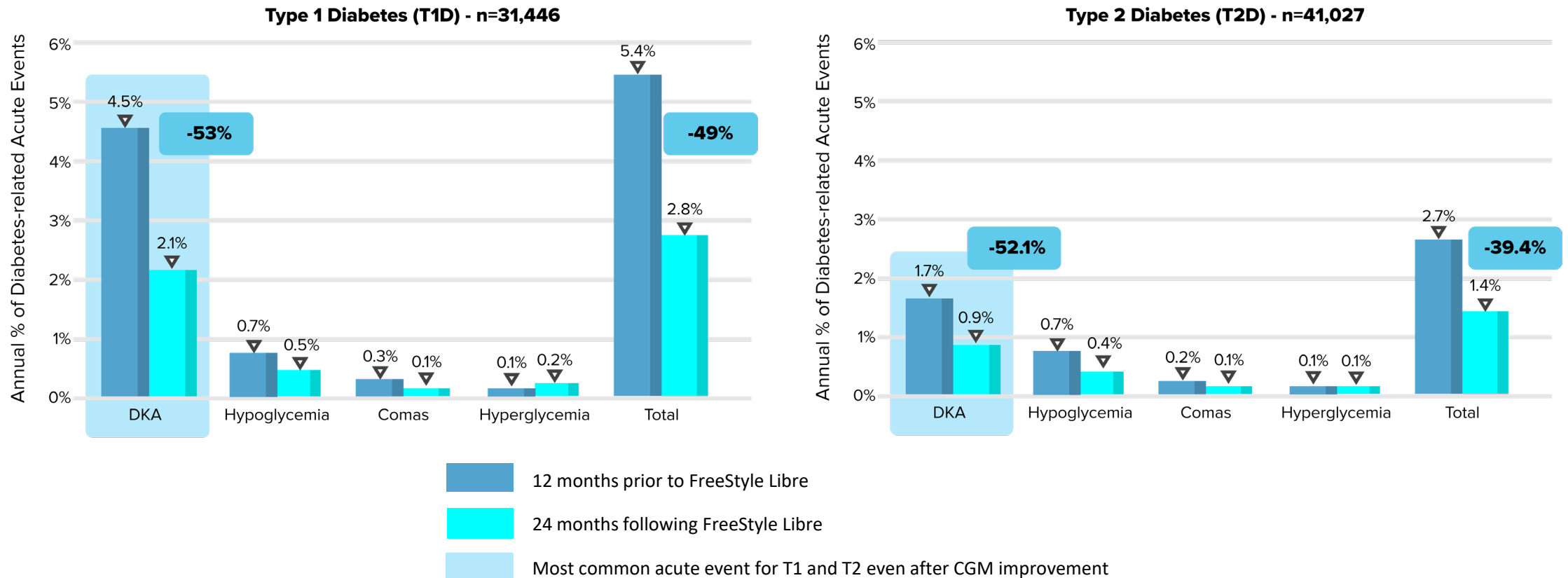
Umpierrez GE, et al. *Diabetes Care*. 2024; Nguyen KT, et al. *JDST*. 2022; Zhong VW, et al. *Diabetes Care*. 2018; Canales SP, et al. *Endocrine Pract*. 2024.

FSL Users Have ~ 50% Decreased Acute Events



Acute diabetes events before and after FreeStyle Libre systems in 74,011 FSL users with T1 or T2D 2015-2018*

RELIEF Study

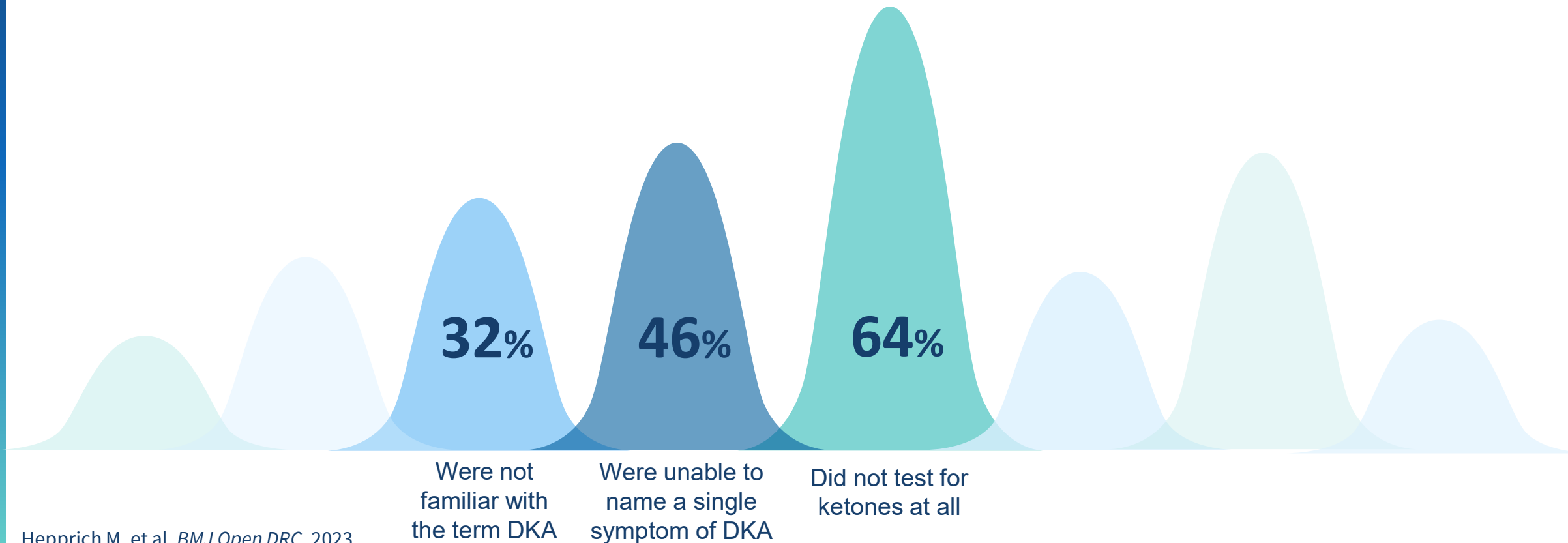


Riveline JP, et al. *Diabetes Technol Ther.* 2022.



DKA Unawareness

Multinational, multicenter survey of endocrine outpatient clinic patients with average duration of T1D of 22 years (N=333)



Hepprich M, et al. *BMJ Open DRC*. 2023.

No Self-Monitoring



< 20%

Test ketone levels, even
when glucose is > 16.7
mmol/L for
1 hour or more

38%

Never test ketones
when nauseated and/or
vomiting

45%

Never test ketone levels
when they
detect a fever

Albanese-O'Neil A, et al. *Diabetes Care*. 2017; Viridi N, et al. *Diabetes Technology & Therapeutics*. 2023.

Monitoring Ketonemia in People with Diabetes: Preliminary Findings from Real-World Studies



- Real-world assessment of ketones in individuals living with type 1 and type 2 diabetes
- Data taken from Freestyle Libre and fingerstick ketone measures.
- 3,023,587 ketone tests performed among 165,108 readers from 89 countries.
- Most (87%) of readings were in normal range.
- Few (1.8%) readings were above the threshold of $>3.0\text{mmol/L}$

MONITORING KETONEMIA

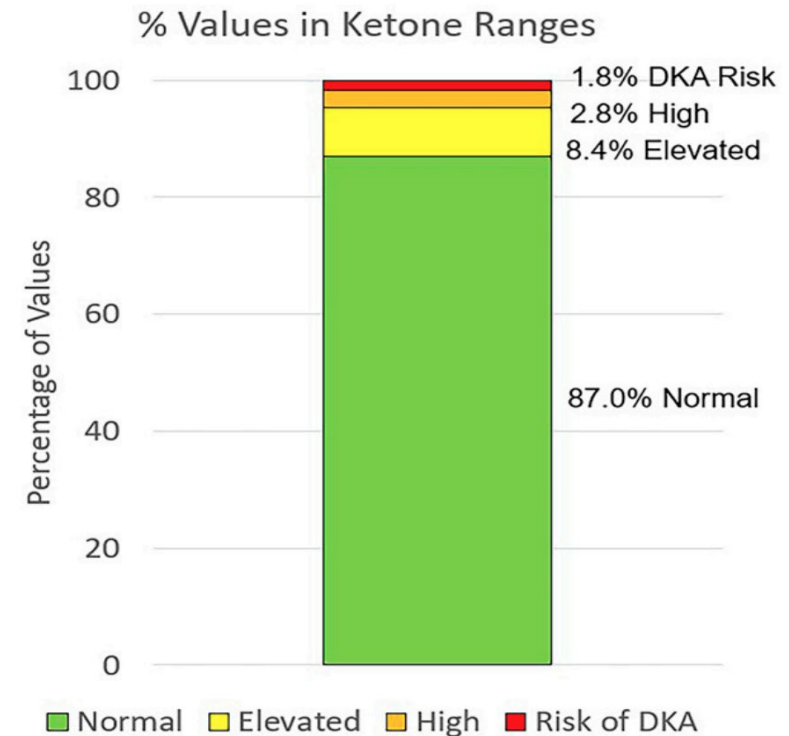


FIG. 1. Ketone test values for all participants ($n = 3,023,587$).

Ketone ranges (normal $[\leq 0.5 \text{ mmol/L}]$, elevated $[>0.5 \text{ to } <1.5 \text{ mmol/L}]$, high $[\geq 1.5 \text{ to } <3.0 \text{ mmol/L}]$, and DKA-risk $[\geq 3.0 \text{ mmol/L}]$)

On the Horizon - CKM



SENSOR

- Continuously monitors glucose and ketone levels every minute without user calibration
- 10-14 days of data storage



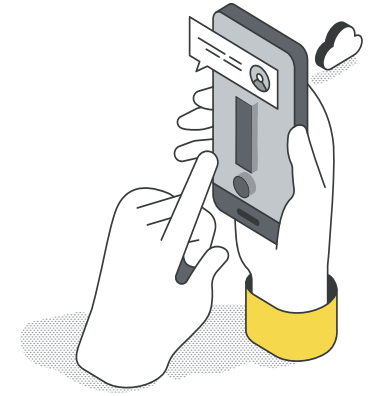
MOBILE APP

- Automatically displays glucose result (value, trend arrow and graph)
- Optional, customizable glucose and ketone alarms



CLOUD SOFTWARE

- Cloud-based software
- Glucose and ketone reports



CAREGIVER APP

- Shared glucose and ketone alarms

Suggested Use



Continuous ketone monitoring for people with diabetes: international expert recommendations on the application of a new technology

Ketan Dhatariya, Richard M Bergenstal*, Mohammed Al-Sofiani, Anastasia Albanese-O'Neill, Tadej Battelino, Kelly Close, Christophe De Block, Sanjoy Dutta, Rodolfo J Galindo, Amin GhavamiNejad, Ahmad Haidar, Julie Heverly, Davida Kruger, Lori M Laffel, Julianne Lally, David M Maahs, Claudio Maffei, Chantal Mathieu, Eden Miller, Medha Munshi, Rimei Nishimura, Kirsten Nørgaard, Tal Oron, David N O'Neal, Monica Oxenreiter, Bruce A Perkins, Moshe Phillip, Eric Renard, Jonathan Rosen, Mauro Scharf, Jennifer Sherr, Carol Wysham, Thomas Danne*

Dhatariya K, et al. *Lancet Diab Endocrinol*. 2026.



Suggested Thresholds

Ketone (BHB) Ranges		Watch for symptoms*	Action to be taken by person with diabetes†
BHB concentration (mmol/L)	3.0	Urgent High Ketones • Deep breathing • Dry lips • Fruity breath • Confusion or difficulty paying attention • Nausea • Vomiting • Abdominal pain • Excess thirst • Frequent urination	Seek immediate medical attention at a hospital or emergency care facility – Monitor glucose levels frequently – Check insulin pump is working as expected or confirm insulin injections have not been missed – Take fluids, carbohydrates and insulin as recommended by your HCP
	1.5	High Ketones • Difficulty breathing • Fruity breath • Confusion or difficulty paying attention • Nausea • Vomiting • Abdominal pain • Fatigue	Follow your HCPs guidance (including changes in medication) and: – Monitor glucose levels frequently – Check insulin pump is working as expected or confirm insulin injections have not been missed – Take fluids, carbohydrates and insulin as recommended by HCP – Contact your HCP
	0.6	Elevated Ketones • Nausea • Vomiting • Abdominal pain • Fatigue	Follow your HCPs guidance (including changes in medication) and: – Monitor glucose levels frequently – Check insulin pump is working as expected or confirm insulin injections have not been missed – Take fluids, carbohydrates and insulin as recommended by HCP
	0.0	Normal Ketones	No action necessary

Dhatariya K, et al. *Lancet Diab Endocrinol*. 2026.



Suggested Graphics

Orientation	Interpretation
	Ketones are rising faster than 0.4 mmol/L/h
	Ketones are changing slowly , less than or equal to 0.4 mmol/L/h
	Ketones are falling faster than 0.4 mmol/L/h

Dhatariya K, et al. *Lancet Diab Endocrinol*. 2026.

Suggested Actions



STOP DKA considerations for bolus insulin and CHO			
Continuous ketone concentration (mmol/L)	Blood glucose meter / CGM value (check every hour)*		
	4.0-8.0 mmol/L (70-150 mg/dL)	8.1-14.0 mmol/L (151-250 mg/dL)	>14 mmol/L (>250 mg/dL)
<0.6 Normal	- No extra insulin - Usual bolus to cover CHO + usual correction		5-10% TDD supplemental insulin or usual correction bolus - Usual bolus to cover CHO
0.6–1.5 Elevated Ketonemia <i>Consider rate of change arrow</i>	5% TDD supplemental insulin + usual bolus to cover CHO 30 - 45 g CHO every 2-4 hours	10% TDD supplemental insulin or 1.5x correction bolus - Usual bolus to cover CHO 30 g CHO every 2-4 hours	10%TDD supplemental insulin or 1.5x correction bolus - Usual bolus to cover CHO every 2-4 hours
1.6–2.9 High Impending DKA <i>Consider rate of change arrow</i>	10% TDD supplemental insulin + usual bolus to cover CHO 30 - 45 g CHO every 2-4 hours	20% TDD supplemental insulin or 2x correction bolus - Usual bolus to cover CHO 30 - 45 g CHO every 2-4 hours	20% TDD supplemental insulin or 2x correction bolus - Usual bolus to cover CHO every 2-4 hours
≥3.0 Urgent High Probable DKA	10% TDD supplemental insulin + usual bolus to cover CHO 30 - 45 g CHO every 2-4 hours	20% TDD supplemental insulin or 2x correction bolus - Usual bolus to cover CHO 30 - 45 g CHO every 2-4 hours	20% TDD supplemental insulin or 2x correction bolus - Usual bolus to cover CHO every 2-4 hours
DKA is likely if ketones remain ≥3 mmol/L (Continuous Ketone System Alarm) despite supplemental insulin			

Dhatariya K, et al. *Lancet Diab Endocrinol.* 2026.

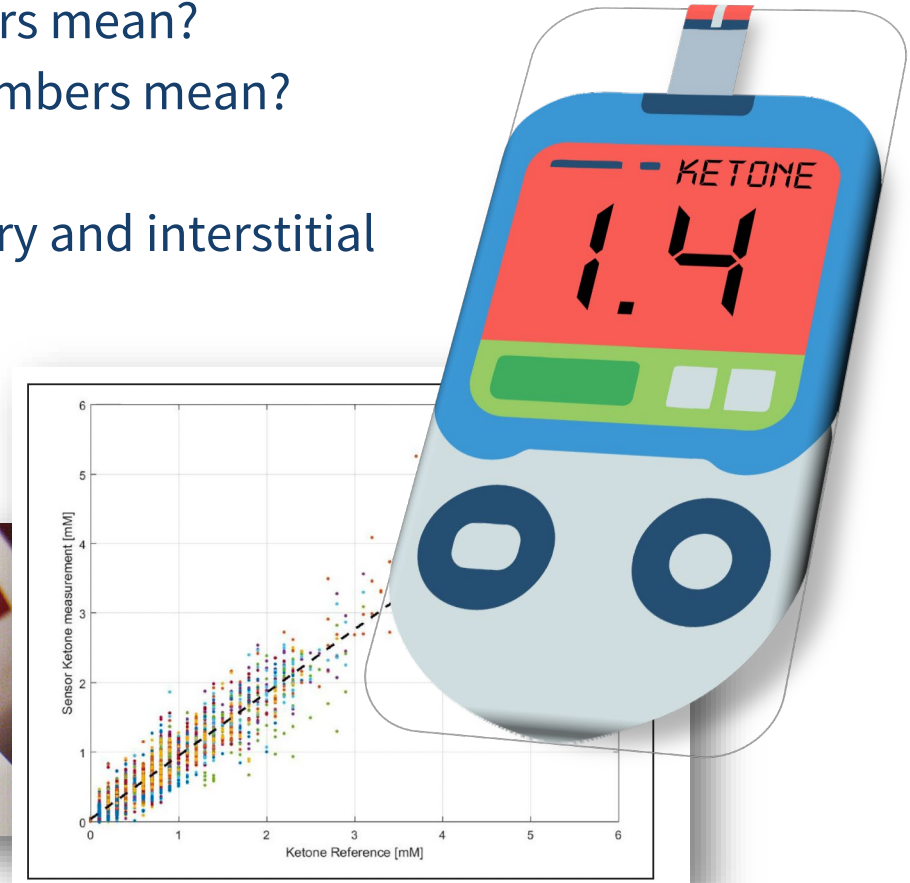
Potentials



- There are several!
 - Helping to identify a rise in ketones allowing the implementation of Sick Day Rules
 - Early warning of pump / infusion set failure
 - Preventing acute illness / hospital admission
 - High risk people may get most benefits – recurrent DKA, poor social circumstance, meal insecurity, homeless, etc
 - Fewer pieces of ‘kit’ to carry about
 - Developing an AID algorithm that incorporates ketones / sick day rules

Challenges & Unknowns

- There are several!
 - Education of people with diabetes – what do the numbers mean?
 - Education of health care professionals – what do the numbers mean?
 - When does physiological become pathological?
 - Are there significant differences between blood / capillary and interstitial fluid?
 - T1DM vs T2DM
 - How to manage euglycaemic ketonaemia/DKA
 - Reimbursement?



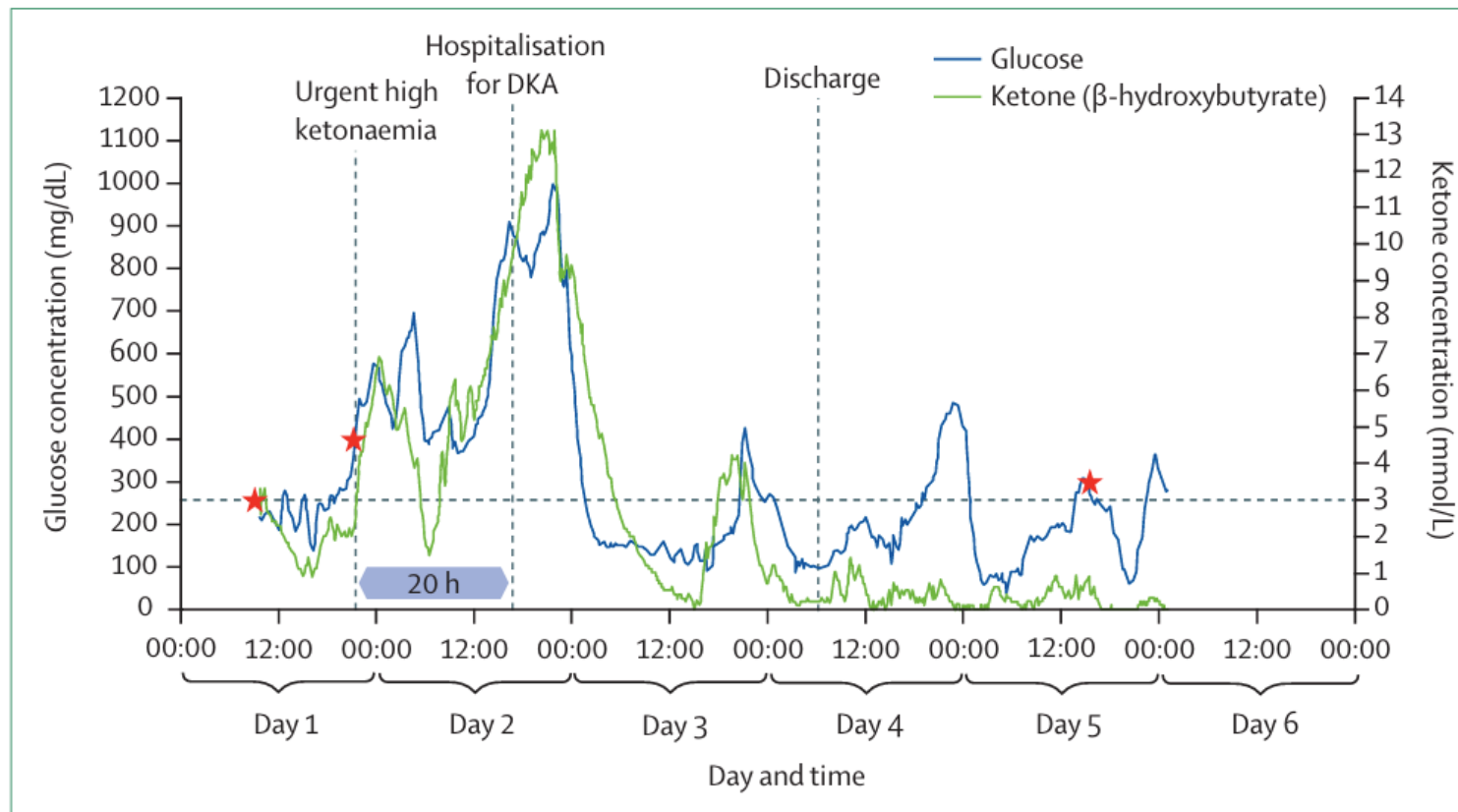
Alva S, et al. *Journal of Diabetes Sci Technol*. 2021.

Interprofessional Team Overview in DKA Care



- Team approach to incorporate this new technology into clinical care delivery is paramount
 - Diabetes educators, dietitians, podiatrists, nurses, physicians, pharmacists, nurse coordinators, social workers, psychologists, advanced practice providers, school nurses, etc.
 - Imperative to discuss this new technology together
 - Awareness of data that these devices can show, and suggested action plans based on that data

Case Study: A 14-year-old girl with T1D enrolled in a study using a blinded glucose/ketone sensor



An urgent high ketone level (≥ 3.0 mmol/L) was measured 20 h before hospitalization with full clinical symptoms of DKA. Resolution of DKA can be seen with initiation of an insulin drip following admission, with a slight elevation in glucose and ketones towards the end of the treatment period.



Key Takeaways

- Ketones are an evolutionary adaptation to prolonged starvation
- Their presence can be beneficial or harmful – depending on the rate of appearance in the circulation
- Continuous ketone measurement seems to be the next logical step in the management of type 1 diabetes, and incorporation into an AID system seems likely
- Challenges remain but the potential for benefit is huge



Reflect on What You Have Learned

How will you apply what you have learned to your practice and with your interprofessional and interdisciplinary diabetes care team?