Plenary Lecture

Measurement of insulin resistance in clinical practice: use of OGTT based techniques

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46th Annual Conference of Endocrine Society of India

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Endocrine Society of India

CV

Masafumi Matsuda, MD, PhD

Research Field:

Metabolism, Endocrinology, Insulin action, Regulation in hypothalamus

Professional Experience

Resident: University of Tokyo Hospital (Hongo, Tokyo, Japan, 6/10/1982)
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Assistant: Internal Medicine, Yamaguchi University (Ube, Yamaguchi, Japan, 6/1/1987)
Physician: Saiki Hospital (Nagato, Yamaguchi, Japan, 6/1/1988)
Clinical Instructor: Diabetes Division, UTHSCSA (San Antonio, Texas, USA, 3/1993)
Instructor: Diabetes Division, UTHSCSA (San Antonio, Texas, USA, 9/1/1994)
Assistant Professor of Medicine: Diabetes Division, UTHSCSA (San Antonio, Texas, USA, 9/1/1996)
Medical Research Director, Clinical Research Center, Texas Diabetes Institute (1997)
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Medical Examination of National Board (Japan)
Board Certificate and Certified Physician for Residency Training in Internal Medicine, Diabetology, Endocrinology and Metabolism (Japan)
Fellow of the Japanese Society of Internal Medicine
Standard ECFMG Certificate (USA) USMLE Step 1, Step 2 and Step 3 passed (USA)

Works original articles 117 (total citation: 7220, *h*-index: 33 from Scopus)

Matsuda M, DeFronzo RA : Insulin sensitivity indices obtained from oral glucose tolerance testing: comparison with the euglycemic insulin clamp. Diabetes Care 22:1462-1470, 1999. (citation:>2600)
Matsuda M: Management of glucose levels in the hospital – theory and practice, Kanehara Ltd. Tokyo, Japan

DISCLOSURE

Presenter: Masafumi Matsuda, MD PhD

The authors have no financial conflicts of interest to disclose concerning the presentation.

Contents

The methods for the measurement of insulin resistance

What is HOMA-IR?

What is Matsuda index?

Limitations

Insulin Resistance

Resistance to "Insulin Treatment"

- **Failure to lower plasma glucose conc.**

  Himsworth HP: Diabetes mellitus: Its differentiation into insulin-sensitive and insensitive types. *Lancet* i:127-130, 1936.

- **More than 100 units per day**
- **More than 1.4 units / kg body weight**

  Flier JS, Kahn CR, Roth J: Receptors, antireceptor antibodies and mechanisms of insulin resistance. *N Engl J Med* 300:413-9, 1979.

Resistance to "Insulin Action"

- **Insulin conc. was Higher in diabetic subjects !**

  Yalow R, Berson S: Immunoassay of endogenous plasma insulin in man. *J Clin Invest* 39:1157-1175, 1960.

Assessment of Insulin Resistance/Sensitivity

[Direct methods]

Lundbaek K: Intravenous glucose tolerance as a tool in definition and diagnosis of diabetes mellitus. *Br Med J* 1:1507-13, 1962. (Insulin loading: non-steady)

Insulin tolerance test

DeFronzo RA, Tobin J, Andres R: Glucose clamp technique: a method for quantifying insulin secretion and resistance. *Am J Physiol* 237:E214-E223, 1979. (insulin & glucose: steady)

Insulin clamp

[Indirect methods]

Turner RC, Holman RR, Matthews D, et al: Insulin deficiency and insulin resistance interaction in diabetes: estimation of their relative contribution by feedback analysis from basal plasma insulin and glucose concentrations. *Metabolism* 28:1086-1096, 1979. (Basal : steady)

HOMA-IR

Bergman RN, Ider YZ, Bowden CR: Quantitative estimation of insulin sensitivity. *Am J Physiol* 236:E667-E677, 1979.

(Glucose loading: non-steady)

Minimal model

Assessment of Insulin Resistance/Sensitivity

Gold standard : Euglycemic insulin clamp

- Direct method
- Steady state assessment (model free)

However,

- Danger of hypoglycemia
  (necessity of the attendance of a medical doctor)
- Cumbersome procedure
- Not physiological

Assessment of Insulin Resistance/Sensitivity

[Direct methods]

Lundbaek K: Intravenous glucose tolerance as a tool in definition and diagnosis of diabetes mellitus. *Br Med J* 1:1507-13, 1962. (insulin: non-steady)

Insulin tolerance test

DeFronzo RA, Tobin J, Andres R: Glucose clamp technique: a method for quantifying insulin secretion and resistance. *Am J Physiol* 237:E214-E223, 1979. (insulin & glucose: steady)

Insulin Clamp

[Indirect methods]

Matsuda M, DeFronzo RA: Insulin sensitivity indices obtained from oral glucose tolerance testing: comparison with the euglycemic insulin clamp. *Diabetes Care* 22:1462-1470, 1999. (Basal：steady & Glucose load: non-steady～steady)

Composite Index

Identify the degree of insulin resistance!

Fasting state;

A:	**PG 90mg/dl**	**insulin 5μU/ml**
B:	**PG 90mg/dl**	**insulin 10μU/ml**
C:	**PG 120mg/dl**	**insulin 10μU/ml**

Identify the degree of insulin resistance!

Fasting state;

			Ratio	Product
A:	PG 90mg/dl	insulin 5μU/ml	90/5=18	90x5=450
B:	PG 90mg/dl	insulin 10μU/ml	90/10=9	90x10=900
C:	PG 120mg/dl	insulin 10μU/ml	120/10=12	120x10=1200

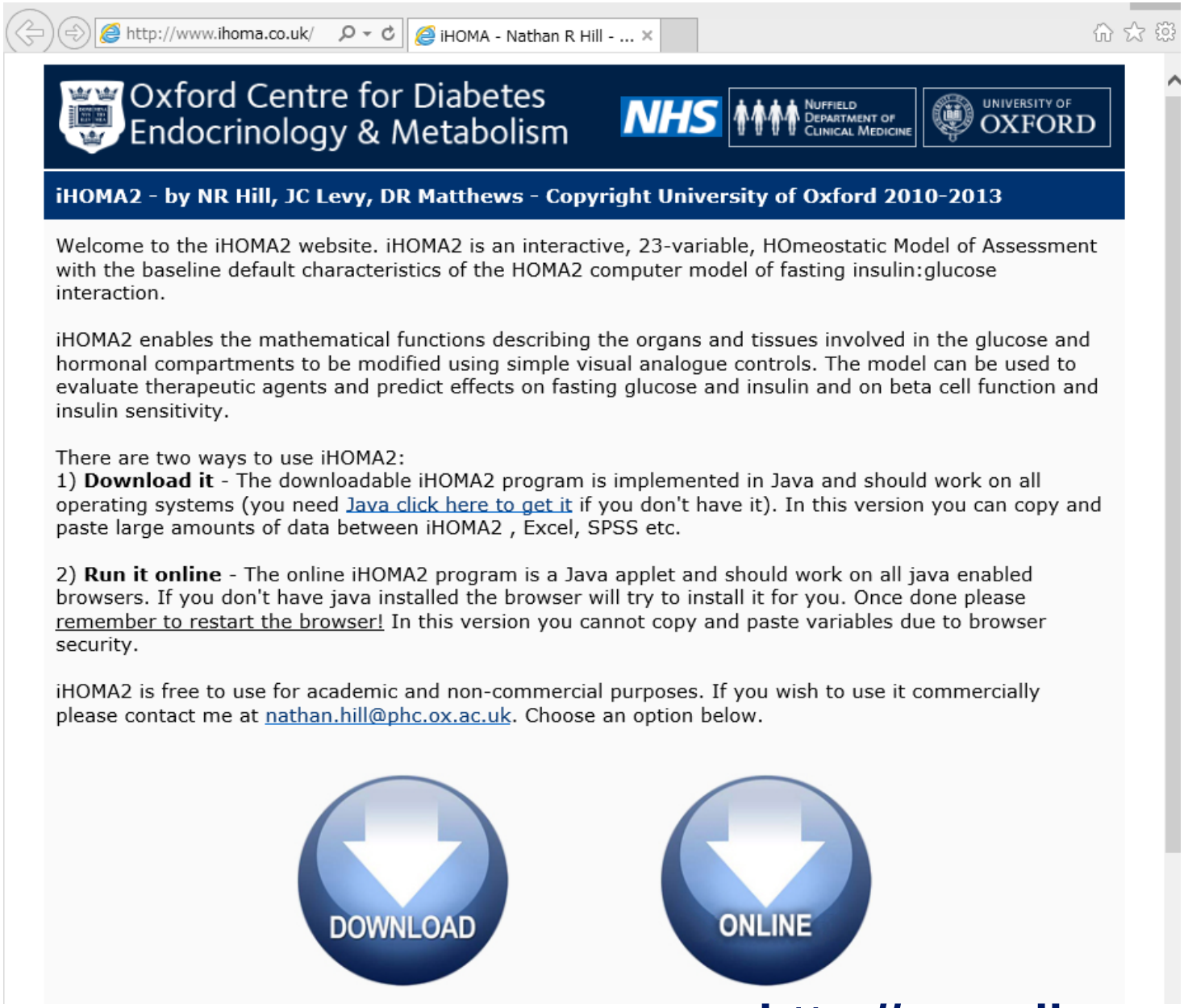
Answer: C, B, A

HOMA

Homeostatic Model Assessment

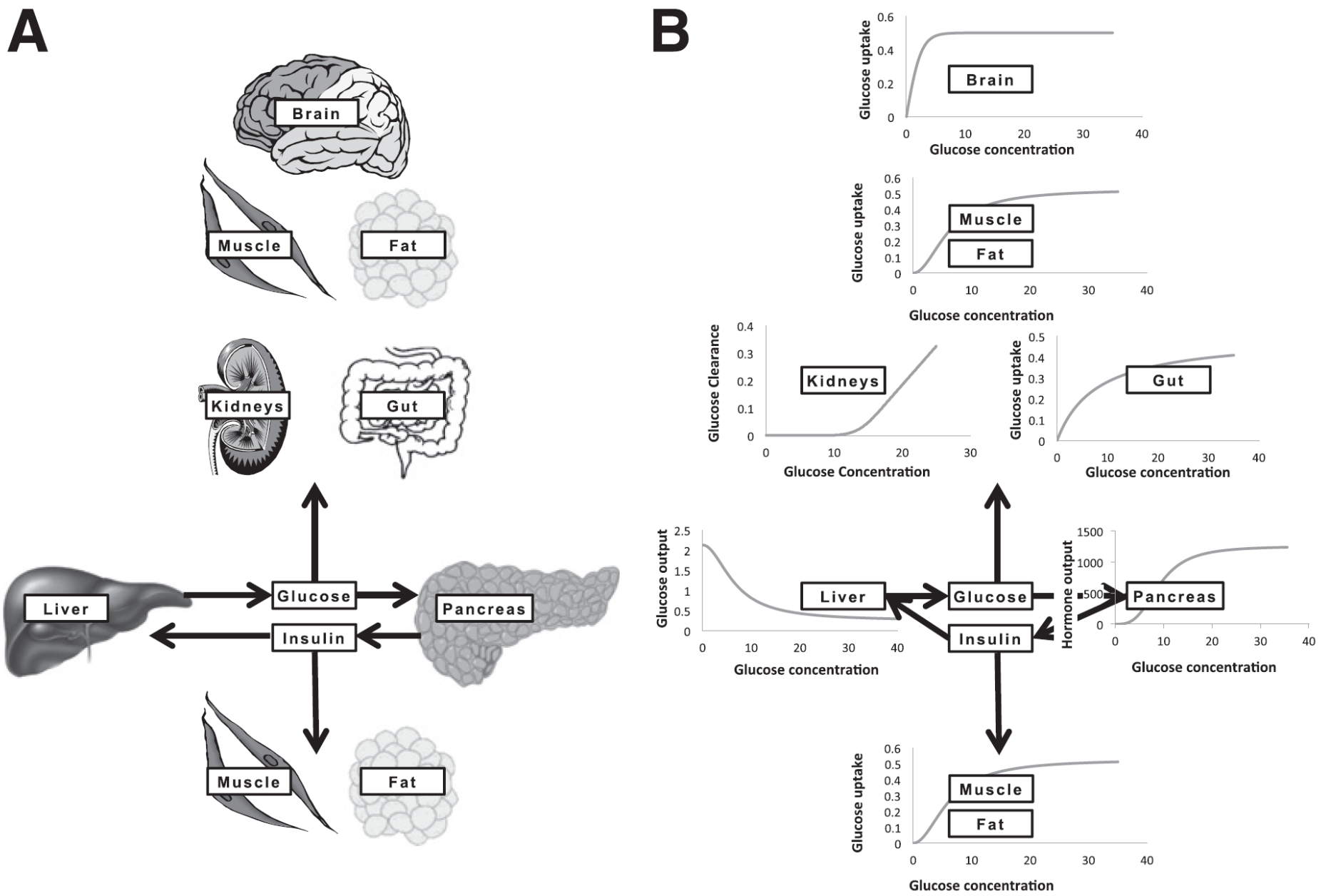
iHOMA2

Diabetes Care 36:2324-30, 2013.

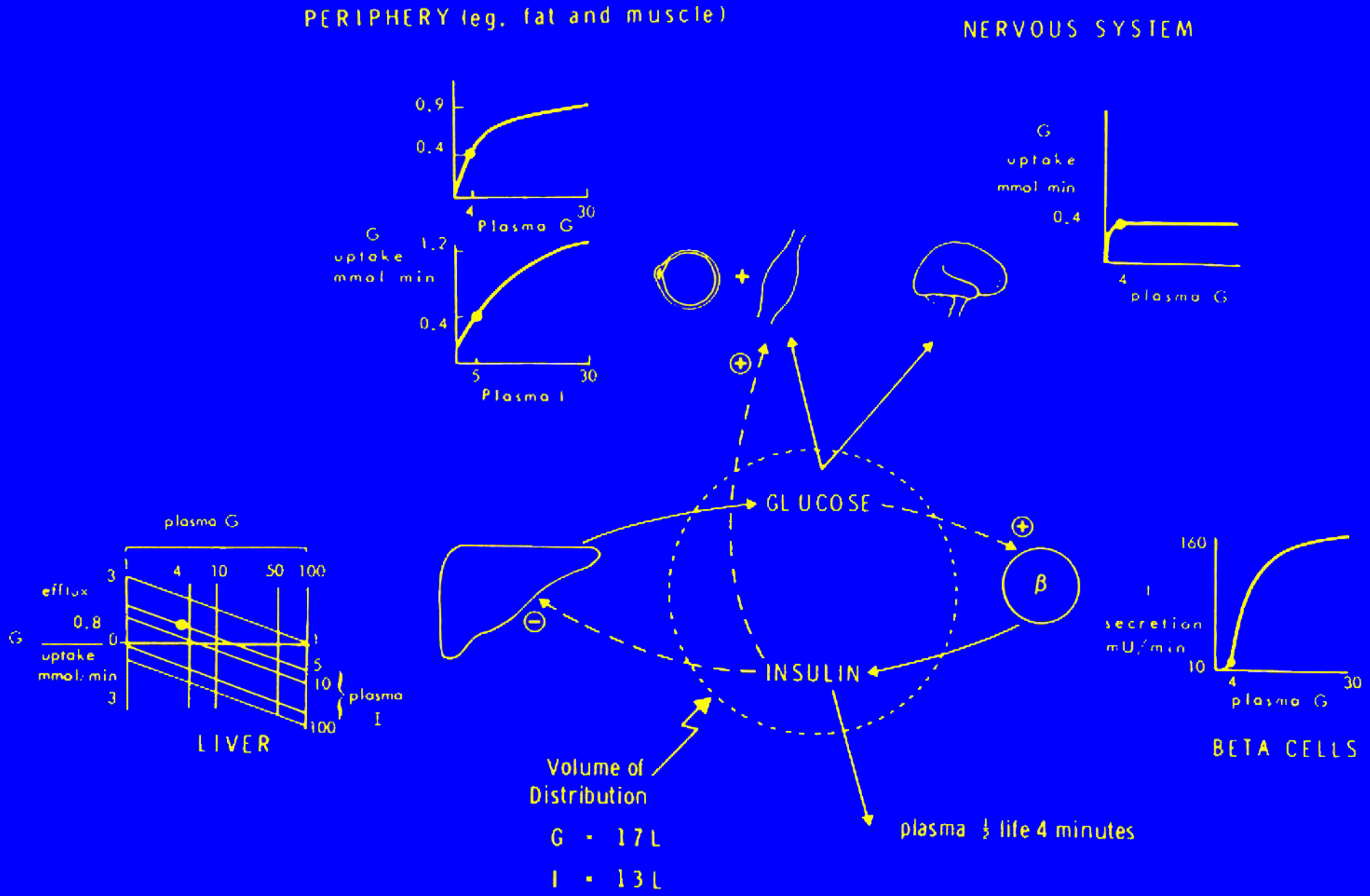


http://www.ihoma.co.uk/

Concept of the iHOMA2



Original Description of the HOMA model

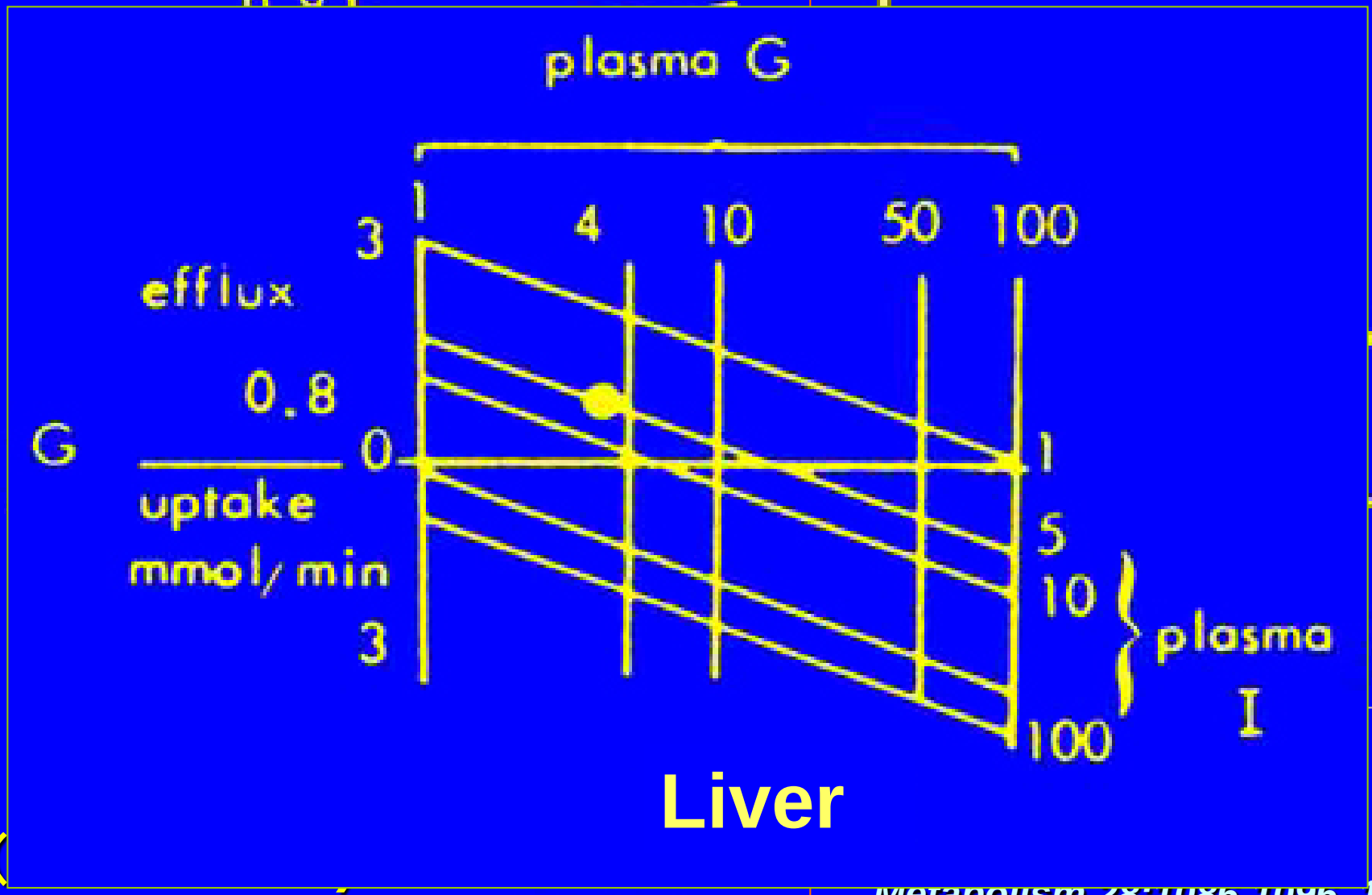


Metabolism 28:1086-1096, 1979

Origina

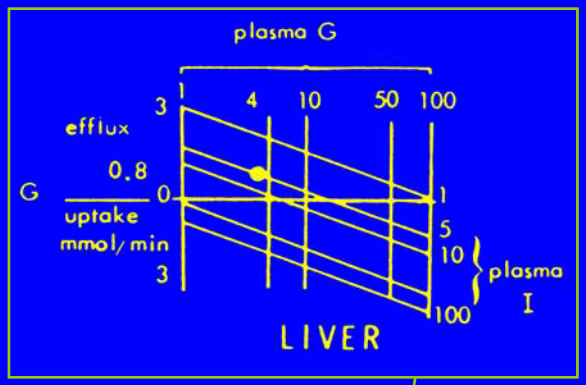
PERIPH

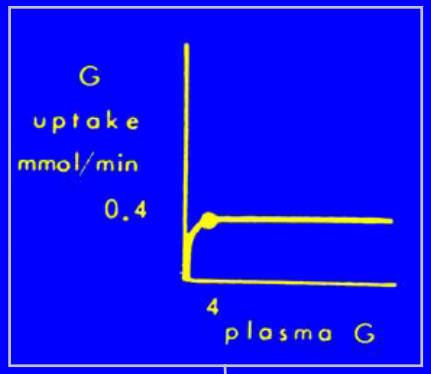
Brain

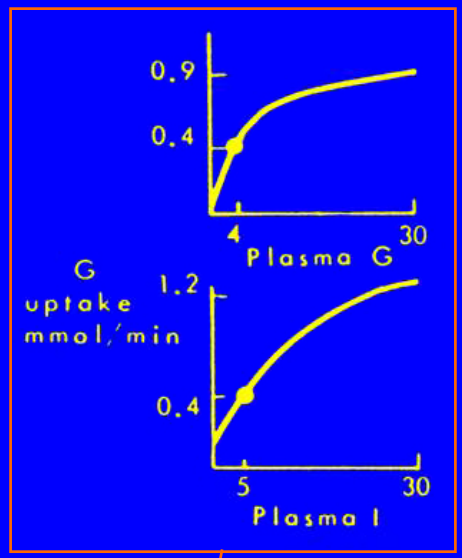


Liver

Metabolism 28:1086-1096, 1979







During the basal steady state:

0= *HGP & Splanchnic* (fPG,fIRI,rl) - *Brain* (fPG) - *Muscle* (fPG,fIRI, rp)

This is converted to the below formula. The unit of PG is mmol/min.

$$0=\left(3-1.86\times\log\left[\frac{fIRI}{rl}\right]-1.5\times\log(fPG)\right)-\frac{0.4}{1+\frac{0.1}{fPG}}-\frac{1.2}{1+\frac{14}{\frac{fIRI}{rp}+2}}\times\frac{1}{0.4}\times\frac{1}{1+\frac{6}{fPG}}$$

Where

fIRI : fasting insulin conc. [mU/L], fPG : fasting PG [mmol/L]
rl : liver insulin resistance, rp : peripheral (or muscle) insulin resistance
Assuming that rl=rp(=R), the above formula can be solved for R after substituting fPG and fIRI for actual measured values.

NOTE: The function above is valid in the steady state.

Calculation of HOMA-IR (example)

$$0=\left[3-1.86\times \log\left[\frac{fIRI}{rI}\right]-1.5\times \log(fPG)\right]-\frac{0.4}{1+\frac{0.1}{fPG}}-\frac{1.2}{1+\frac{14}{\frac{fIRI}{rp}+2}}\times\frac{1}{0.4}\times\frac{1}{1+\frac{6}{fPG}}$$

fIRI=8 [μU/ml] , fPG=6 [mmol/L]

Then,

$$0=\left[3-1.86\times \log\left[\frac{8}{rI}\right]-1.5\times \log(6)\right]-\frac{0.4}{1+\frac{0.1}{6}}-\frac{1.2}{1+\frac{14}{\frac{8}{rp}+2}}\times\frac{1}{0.4}\times\frac{1}{1+\frac{6}{6}}$$

Thus,

rI ?, rp ? (when fIRI=8 μU/ml, fPG=108mg/dl(=6mmol/L))

M. Matsuda: index of insulin secretion and insulin resistance, Internal Medicine [Japanese] 105:39-44, 2010.

Calculation of HOMA-IR (example)

$$0=\left[3-1.86\times \log\left[\frac{fIRI}{rI}\right]-1.5\times \log(fPG)\right]-\frac{0.4}{1+\frac{0.1}{fPG}}-\frac{1.2}{1+\frac{14}{\frac{fIRI}{rp}+2}}\times\frac{1}{0.4}\times\frac{1}{1+\frac{6}{fPG}}$$

rI=rp(=R), fIRI=8 [μU/ml] , fPG=6 [mmol/L]

Then,

$$0=\left[3-1.86\times \log\left[\frac{8}{R}\right]-1.5\times \log(6)\right]-\frac{0.4}{1+\frac{0.1}{6}}-\frac{1.2}{1+\frac{14}{\frac{8}{R}+2}}\times\frac{1}{0.4}\times\frac{1}{1+\frac{6}{6}}$$

Thus,

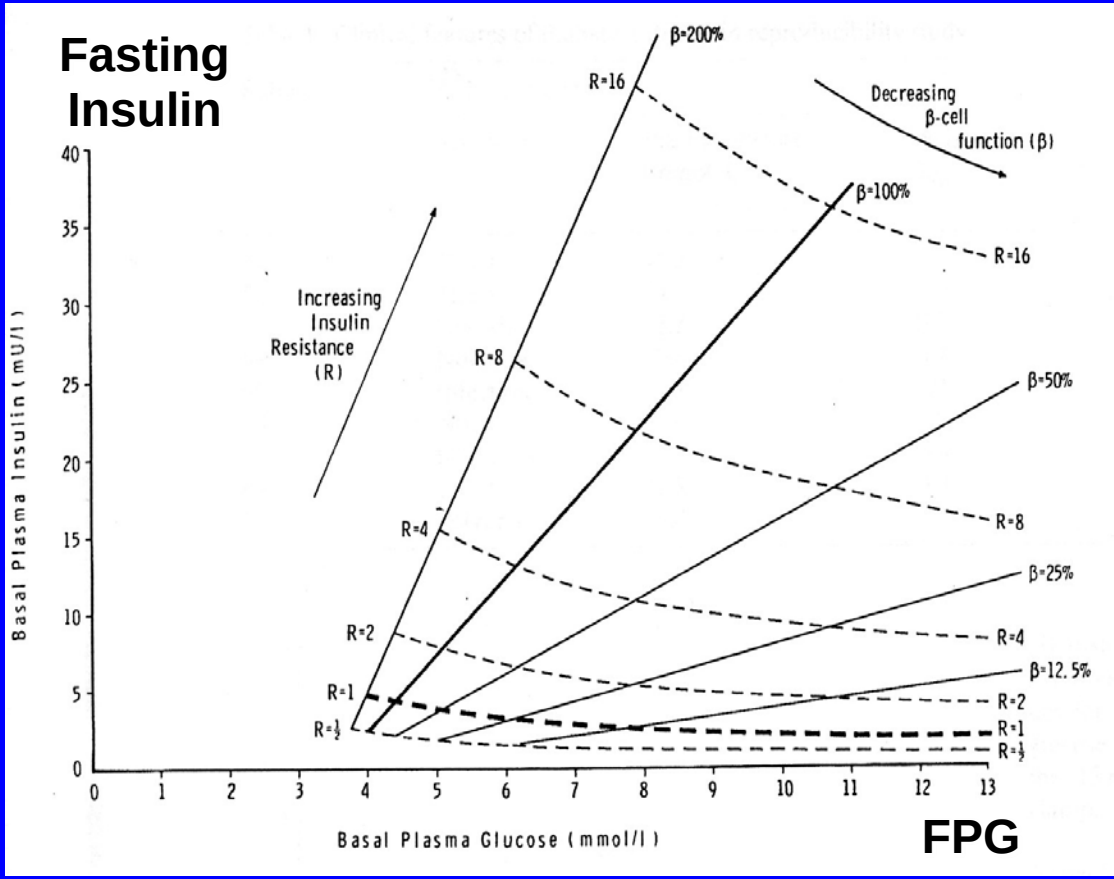
R=2.1 (when fIRI=8 μU/ml, fPG=108mg/dl(=6mmol/L))

It was possible to solve this equation by a large frame computer in 1979. Now it is easy to solve this equation by an EXCEL file.

Note: this calculation was estimated from the figures found in the original *Metabolism* paper published in 1979. It may possible that Dr. Turner used a different formula.

M. Matsuda: index of insulin secretion and insulin resistance, Internal Medicine [Japanese] 105:39-44, 2010.

Induction of Simplified HOMA formula



Reduced formula

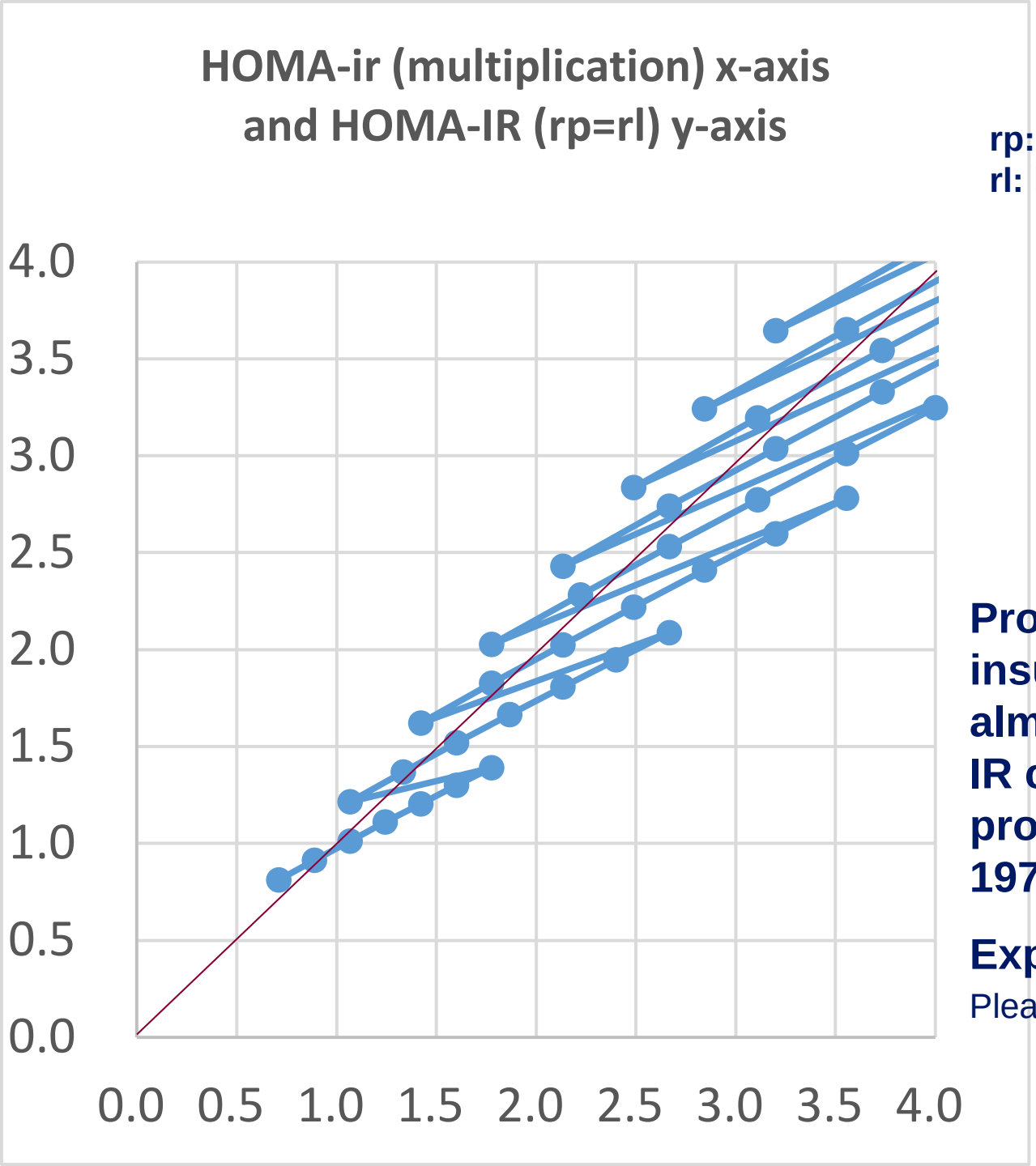
(1985 by Matthews D et al.)

$$\textbf{HOMA-IR} = \frac{\text{fIRI}}{22.5e^{-\ln(\text{fPG})}} = \frac{\text{fIRI} \times \text{fPG}}{22.5}$$

$$\textbf{HOMA-}\beta\textbf{\%} = \frac{20 \times \text{fIRI}}{\text{fPG} - 3.5}$$

Approximation of HOMA-IR and HOMA-β%

***Diabetologia* 28:412-419, 1985**



rp: peripheral insulin resistance
rl: liver insulin resistance

Product of FPG and fasting insulin conc. (on y-axis) is almost equal to the HOMA-IR calculated by the model proposed by Turner et al, 1979 (n x-axis).

Expressed by ●

Please neglect the connection lines.

QUICKI and HOMA %S

$$\mathrm{QUICKI} = \frac{1}{log(\mathrm{I}_0) + log(\mathrm{G}_0)}$$

$$\mathrm{QUICKI} = \frac{1}{log(\mathrm{I}_0 \times \mathrm{G}_0)} = \frac{1}{log(22.5 \times \mathrm{HOMA} - \mathrm{IR})}$$

Kats A, Nambi SS, Mather K et al: Quantitative Insulin-Sensitivity Check Index (QUICKI): a simple, accurate method for assessing insulin sensitivity in humans. *J Clin Endocrinol Metab* 85:2402-2410, 2000.

$$\mathrm{HOMA}\ \%S = \frac{100}{\mathrm{HOMA} - \mathrm{IR}}$$

Wallace TM, Levy JC, Matthews DR.: Use and abuse of HOMA modeling. Diabetes Care 27:1487-95, 2004.

The computer model gives a value for insulin sensitivity expressed as HOMA2-%S (where 100% is normal), which is simply the reciprocal of HOMA2-IR.

Improvement of HOMA

- Whole body insulin sensitivity

  Matsuda Index

- Specificity to the liver and the muscle

  Modified HOMA

Introduction of Matsuda index

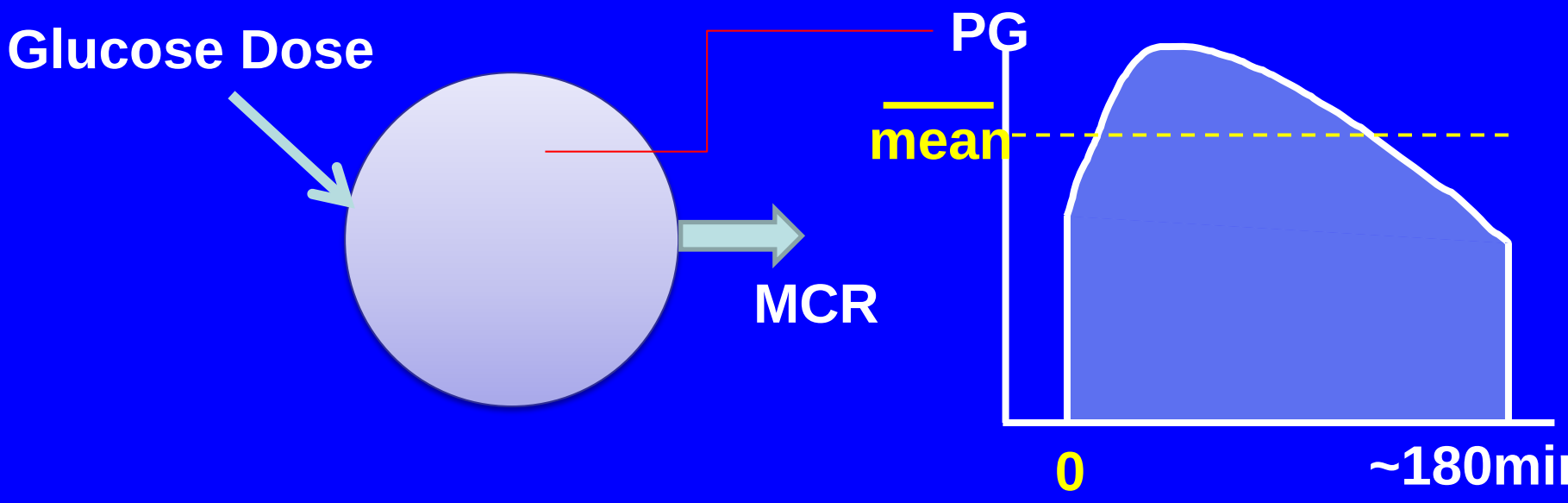
Depicted by Dr. Ralph A. DeFronzo.

After glucose administration

MCR (metabolic clearance rate)

$$= \frac{\text{Dose of glucose}}{\text{AUC of PG conc.}}$$

(non- steady state)



After glucose administration

Insulin Sensitivity during OGTT

can be estimated by

$$\frac{\text{MCR of glucose}}{\text{Average Insulin conc.}}$$

$$= \frac{\text{Dose of glucose}}{\overline{\text{PG}} \times \overline{\text{Insulin}}}$$

Induction of Matsuda index

INDEX OF INSULIN RESISTANCE DERIVED FROM OGTT

Insulin Resistance (Basal)* = G_O X I_O

Insulin Resistance (OGTT)** = G X I

*primarily reflects liver

**reflects both muscle > liver

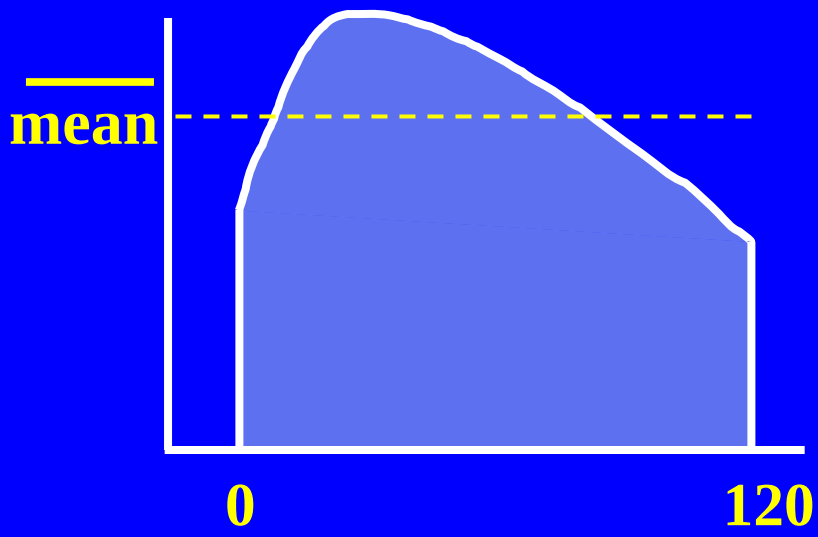
→ Inverse of Geometric Mean

Insulin sensitivity indices obtained from oral glucose tolerance testing

$$ISI(comp) = \frac{10{,}000}{\sqrt{(FPG \times FPI) \times (\bar{G} \times \bar{I})}}$$

$$\bar{G} = \frac{1}{120}\int_0^{120} g(t)\ dt$$

$$\bar{I} = \frac{1}{120}\int_0^{120} i(t)\ dt$$



Usually we have OGTTs with 120 minutes. And the initial validation was done from the data up to 120 min.

Matsuda M, DeFronzo RA.: Diabetes Care 22(9):1462-70, 1999.

ISI(comp)

(Composite Index, Matsuda's Index)

$$\mathrm{ISI(comp)} = \frac{10000}{\sqrt{g_0 \times i_0 \times \frac{(g_0 \cdot 15 + g_{30} \cdot 30 + g_{60} \cdot 30 + g_{90} \cdot 30 + g_{120} \cdot 15)}{120} \times \frac{(i_0 \cdot 15 + i_{30} \cdot 30 + i_{60} \cdot 30 + i_{90} \cdot 30 + i_{120} \cdot 15)}{120}}}$$

g_0 : Basal PG, g_{30} : PG at 30 min, g_{60}: PG at 60 min, g_{90} : PG at 90 min, g_{120} : PG at 120 min

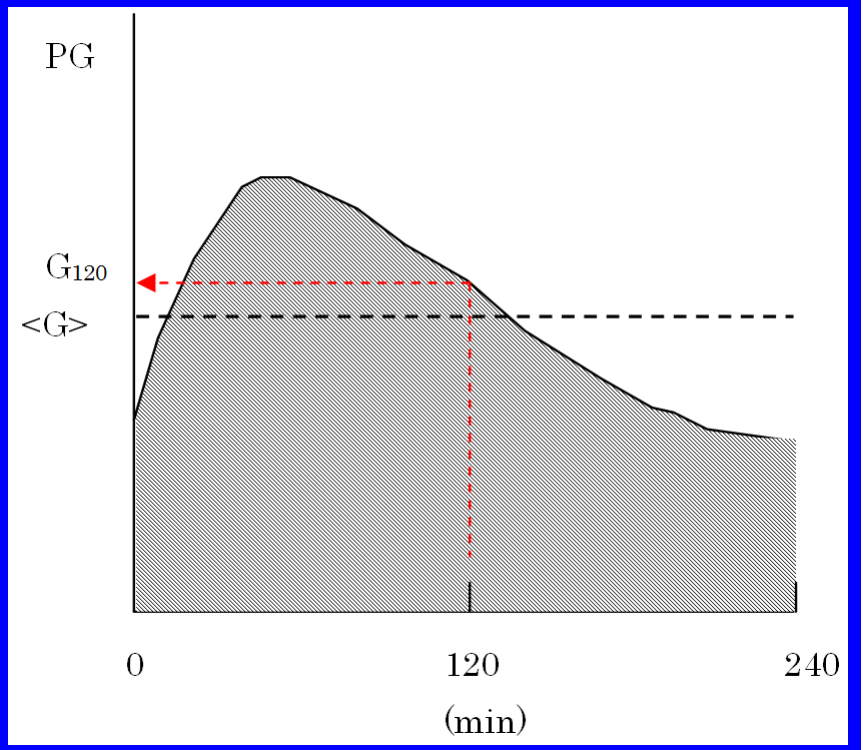
i_0 : Basal IRI, i_{30} : IRI at 30 min, i_{60}: IRI at 60 min, i_{90} : IRI at 90 min, i_{120} : IRI at 120 min

Mean (range, ±SD) in healthy young persons

New Haven, CT (n=37)	**5.43 (2.7-9.6, ±1.9)**
San Antonio, TX (n=62)	**4.34 (1.0-11.0, ±2.6)**

Correlation with clamp: r ≧ 0.73

Matsuda M, DeFronzo RA: Insulin sensitivity indices obtained from oral glucose tolerance testing. Comparison with the euglycemic insulin clamp. *Diabetes Care* 22: 1462-1470, 1999.



$$ISI\,(comp) = \frac{10,000}{\sqrt{(FPG \times FPI) \times (\bar{G} \times \bar{I})}}$$

$$ISI\,(comp) = \frac{10,000}{\sqrt{(FPG \times FPI) \times (G_{120} \times I_{120})}}$$

OBSERVATIONS

Reduced Time Points to Calculate the Composite Index

Since the original publication of the composite (Matsuda) index for the measurement of insulin sensitivity from plasma glucose and insulin concentrations during the oral glucose tolerance test (OGTT) (1), this index has been widely used by investigators throughout the world. According to Scopus, more than 1,000 articles have cited the original article (1) during the last 10 years, and several modifications of this index have been published (2,3). Although the basic idea is to use the plasma insulin and glucose areas under the curve (AUCs), the actual time points at which plasma insulin and glucose levels are measured during the OGTT may be few and the time intervals may not be equal.

In some studies, fewer time points, usually 0, 60, and 120 min or only 0 and 120 min, have been obtained during the OGTT. We show here that calculation of the composite index using these fewer time points agrees well with the original calculation, which was based on five plasma glucose and insulin measurements. Although it is difficult to imagine a reasonable AUC when samples from only 0 and 120 min are available, the simple index below works quite well.

$$ISI(composite) = k/sqrt(G_0 \times I_0 \times G_{120} \times I_{120})$$

where ISI(composite) is the insulin sensitivity index, k (= 10,000) is a constant that provides numbers that are easy to deal with, G_0 and G_{120} represent the plasma glucose concentrations at times 0 and 120 min, I_0 and I_{120} represent the plasma insulin concentrations at times 0 and 120 min, and sqrt is the mathematical function to calculate the square root. Thus, all of the calculations are based on the concept of the original publication.

Using the data from the original publication (N = 153) (1), correlation coefficients were calculated relating whole-body ISI(composite) to *1*) the rate of insulin-stimulated glucose disposal (R_d) during the euglycemic insulin clamp and *2*) hepatic insulin sensitivity (His) measured with tritiated glucose: His = 1,000/HGP × FPI, where HGP is hepatic glucose production, the primary determinant of fasting plasma glucose level, and FPI is fasting plasma insulin. R_d (or His) and an ISI(composite) calculated from 0, 30, 60, 90, and 120 min (set A); 0, 60, and 120 min (set B); and 0 and 120 min (set C) were significantly ($P < 0.01$) correlated with $r = 0.732$ ($r = 0.670$) in set A, $r = 0.741$ ($r = 0.680$) in set B, and $r = 0.772$ ($r = 0.651$) in set C.

Although ISI(composite) calculated using different time points cannot be compared between different studies, within any given study the index provides a reasonable index of whole-body insulin sensitivity.

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DOI: 10.2337/dc10-0646

Acknowledgments— R.A.D. and M.M. both wrote the manuscript, reviewed/edited the manuscript, contributed to the discussion, and research the data.

References

1. Matsuda M, DeFronzo RA. Insulin sensitivity indices obtained from oral glucose tolerance testing: comparison with the euglycemic insulin clamp. Diabetes Care 1999;22:1462–1470
2. Abdul-Ghani MA, Matsuda M, Balas B, DeFronzo RA. Muscle and liver insulin resistance indexes derived from the oral glucose tolerance test. Diabetes Care 2007;30:89–94
3. Radaelli T, Farrell KA, Huston-Presley L, Amini SB, Kirwan JP, McIntyre HD, Catalano PM. Estimates of insulin sensitivity using glucose and C-Peptide from the hyperglycemia and adverse pregnancy outcome glucose tolerance test. Diabetes Care 2010;33:490–494

Cut off value for Insulin Resistance

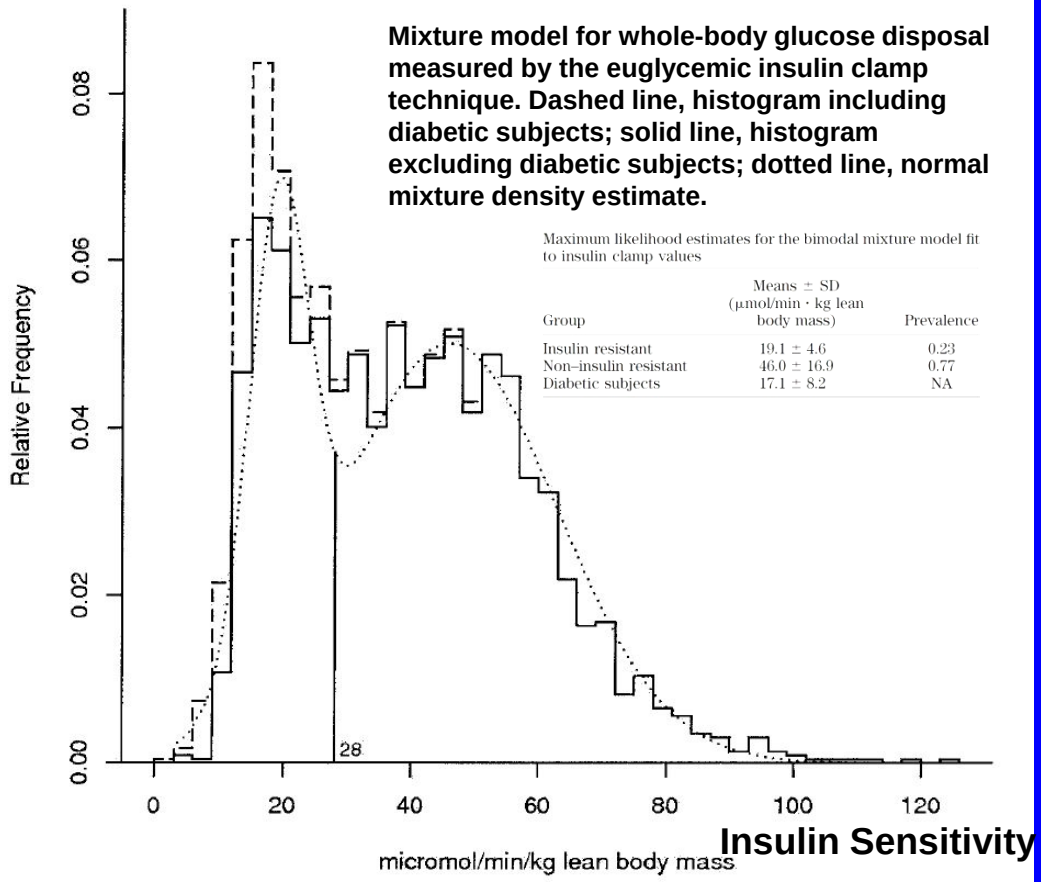
2,321 (2,138 nondiabetic) euglycemic insulin clamp studies

European Group for the Study of Insulin Resistance (EGIR) project (n = 1,436)

Pima Indian Study (n = 597)

San Antonio (n = 288, of whom 99 were Mexican American)

The EGIR studies were performed on Caucasians from 17 European sites (Athens, Greece; Baden, Heidelberg, Kreisha, and Munich,Germany; Belgrade, Serbia; Geneva, Switzerland; Goteborg, Sweden; Helsinki and Kuopio, Finland; Odense, Denmark; and Naples, Padova, Pisa, Rome,Torino, and Verona, Italy).



Mixture model for whole-body glucose disposal measured by the euglycemic insulin clamp technique. Dashed line, histogram including diabetic subjects; solid line, histogram excluding diabetic subjects; dotted line, normal mixture density estimate.

Maximum likelihood estimates for the bimodal mixture model fit to insulin clamp values

Group	Means ± SD (μmol/min · kg lean body mass)	Prevalence
Insulin resistant	19.1 ± 4.6	0.23
Non–insulin resistant	46.0 ± 16.9	0.77
Diabetic subjects	17.1 ± 8.2	NA

Cut off Value

Rd: <28 mmol/min per kg LBM
(5.0 mg/min per kg LBM)
(200 mg/min per m^2)

ISI(comp): < ~ 3.1
HOMA-IR: > ~ 2.8

Diagnosis of insulin resistance

(if any of the following conditions are met)

BMI >28.9 kg/m^2

HOMA-IR>4.65
BMI >27.5 kg/m^2
and HOMA-IR >3.60

(Sensitivity 84.9%, Specificity 78.7%)

Diabetes 54:333–339, 2005

Cut off Value Calculation

from the data set used to introduce ISI(comp)

Rd<200mg/m^2 per min as the gold standard

	Sensitivity	Specificity
BMI≧28.0	83%	65%
BMI≧30.0	66%	80%
(Rd vs BMI: r=-0.45)		
HOMA-IR≧2.50	84%	69%
HOMA-IR≧2.80*	80%	77%
(Rd vs HOMA-IR: r=-0.44)		
ISI(comp)＜3.1	76%	71%
ISI(comp)＜2.6*	71%	84%
(Rd vs ISI(comp): r=0.73)		
Model	91% (85%¶)	62% (79%¶)

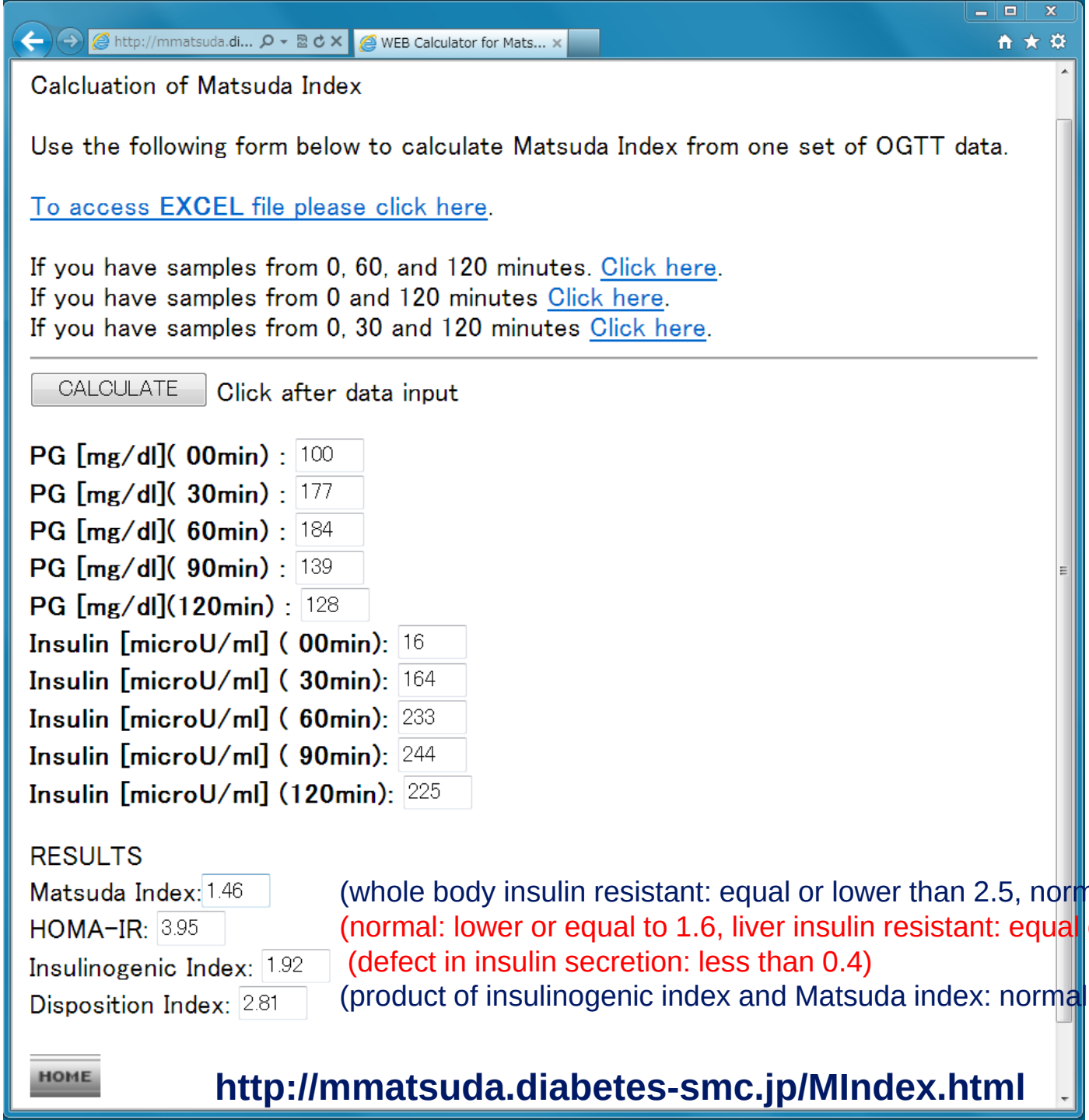
BMI >28.9 kg/m^2 or HOMA-IR>4.65 or (BMI >27.5 kg/m^2 and HOMA-IR >3.6)

(Data set used in *Diabetes Care* 22: 1462, 1999)

*:best value by ROC analysis

¶: shown in *Diabetes* 54:333–339, 2005

ISI(comp)=2.5 was used as a cut-off in Kerman WN, et al: Pioglitazone improves insulin sensitivity among non diabetic patients with a recent transient ischemic attach or ischemic stroke. *Stroke* 34:1431-6, 2003



(whole body insulin resistant: equal or lower than 2.5, normal range: 5~8)

(normal: lower or equal to 1.6, liver insulin resistant: equal or more than 2.5.)

(defect in insulin secretion: less than 0.4)

(product of insulinogenic index and Matsuda index: normal: more than 1)

http://mmatsuda.diabetes-smc.jp/MIndex.html

https://sites.google.com/a/sl

I. R. CALCULATOR - OGTT-P...

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" OGTT - PLUS "

OGTT-Plus : Introduction | How To Use? | I. R. CALCULATOR | Examples | B.C.F. CALCULATOR | Contact Me

R. CALCULATOR

Note: Mobile users are requested to view this page sideways.
Press the "Three Lines Symbol" to open the Main Menu.

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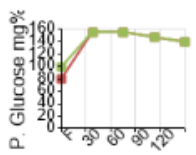
"OGTT-Plus" Insulin Resistance Calculator

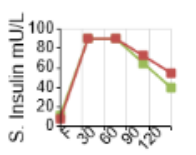
Patient Name :	Patient's Name goes here ..	16-Oct-16
Patient Information :	Patient's relevant information goes here ..	
Is a known Diabetic ?	No	

OGTT 75 Gm glucose	Fasting	30 min	60 min	120 min
SUGAR mg%	80	155	155	139
INSULIN microU/ml	8	90	90	55

OGTT-Plus Results will be displayed automatically ! Watch below this line !



Glucose Graph. Green-Normal, Red-Patient



Insulin Graph. Green-Normal, Red-Patient

FASTING INDICES		POST-GLUCOSE INDICES	
HOMA IR Basal I.R. Index Normal < 2.7	1.58	Matsuda wholeBody I.R. Index Normal < 0.33 (1/ Matsuda ISI)	0.25
HOMA 1 - Basal Disposition Index Normal > 75%	107.21	ISSI-2 - OGTT Disposition Index Normal > 158	243.66
I.G.I. Insulinogenic Index Less if < 0.4; Normal upto 0.86	1.09	OGTT-Plus Analysis Category	NoDM

COMMENTS : (Based on OGTT-Plus results)	
1. "Liver Insulin Resistance" =>	Normal.
2. "Whole Body Insulin Resistance" =>	Normal.
3. Pancreatic Insulin Secretion =>	Pancreas is working more !
4. Beta Cells Function(ISSI2) =>	Normal.
5. OGTT-Plus result suggests =>	You have increased Whole Body I.R.!

References *1. HOMA IR = ((Fasting Glucose)*(Fasting Insulin))/405 ; HOMA 2% = (360*(Fasting Insulin))/(Fasting Sugar -63) ; 2. Matsuda Whole Body Insulin Sensitivity = 1/ sq.rt.((GUF*InsF*GUMean*InsMean)) ; 3. IGI - Insulinogenic Index = (Insulin30-f)/(Glucose30-f) ; 4. ISSI-2 = ((AUC Insulin/AUC Glucose)*Matsuda ISI) ; 5. Glucose Tolerance Comments are based on OGTT sugar values and Matsuda Insulin sensitivity.*

http://www.ogttplus.com

HOMA-IR and Matsuda index when a SGLT-2 inhibitor is used.

when rl = rp (=R), it is possible to solve the above equation and R is HOMA-IR (a similar value as published).

mmol of glucose per whole body per min

p * V * dg/dt = Ra(liver) − Rd(brain) − Rd(peripheral tissue) − u

u =	0 mmol per min
fIRI =	**8 microU/ml**
fPG =	**6 mmol/L** **(108mg/dL)**
R = rl =	**1.973**
R = rp =	**1.973 (rp=rl)**
p =	1
V =	15 L
dg/dt=	**0 in steady state**

	mmol	mg
pV dg/dt	0.000	0.0
Ra(liver)	0.702	126.4
Rd(brain)	0.393	70.8
Rd(peripheral)	0.308	55.5
u	0.000	0.0

When SGLT-2 inhibitor is used

urine excretion is 60g per day

u =	**0.231 mmol per min**
fIRI =	**8 microU/ml**
fPG =	**6 mmol/L** **(108mg/dL)**
R = rl =	**2.518**
R = rp =	**2.518 (rp=rl)**
p =	1
V =	15 L
dg/dt=	**0 in steady state**

	mmol	mg
pV dg/dt	0.000	0.0
Ra(liver)	0.899	161.8
Rd(brain)	0.393	70.8
Rd(peripheral)	0.274	49.3
u	0.231	41.7

Assuming same fIRI and fPG, addition of urine excretion,
there is a change the index of insulin resistance (R = rl = rp)
However,
according to Dr.DeFronzo, rl may be increased, while rp is decreased.
see Merovci A, and Abdul-Ghani MA, DeFronzo RA et al.J Clin Invest. 2014 Feb 3;124(2):509-14

Letter from Dr. Matthews:

Subject: Re: HOMA-IR under use of SGLT-2 inhibitors

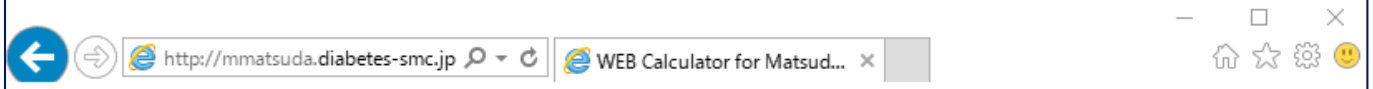
Hi,
HOMA doesn't give the correct answer when used with SGLT2 inhibitors since the effect of insulin appears greater as more glucose is cleared... So you need to use iHOMA, and change the renal threshold appropriately as described in our Diabetes Care paper:

Hill NR, Levy JC, Matthews DR. Expansion of the homeostasis model assessment of beta-cell function and insulin resistance to enable clinical trial outcome modeling through the interactive adjustment of physiology and treatment effects: iHOMA2. Diabetes Care. 2013; 36:2324-30.

Best wishes

David

Prof. David R. Matthews
Professor of Diabetes Medicine, University of Oxford Emeritus Chairman,
Oxford Centre for Diabetes, Endocrinology and Metabolism (OCDEM).
Medical tutor, Harris Manchester College, Oxford



Calcluation of Matsuda Index

Use the following form below to calculate Matsuda Index from one set of OGTT data.

To access **EXCEL** file please click here.

If you have samples from 0, 30, 60, and 120 minutes. Click here.
If you have samples from 0, 60, and 120 minutes. Click here.
If you have samples from 0 and 120 minutes Click here.
If you have samples from 0, 30 and 120 minutes Click here.

Please use as many as possible measurements to calculate the AUC (area under the curve) of responses of glucose and insulin, preferably until the return to the basal state (i.e., up to 180 or 240 minutes), although this site does not support the calculation. Matsuda index uses the metabolic clearance rate during the OGTT. Option of different doses other than 75 g of glucose has not been well validated. Use the same way of calculation for comparison.

CALCULATE Click after data input

Dose [g] (usually 75g) : 75
When you use a SGLT-2 inhibitor, examine urine excretion and subtract from 75(g) and input it to the upper box! for calculation see click here

PG [mg/dl](00min) : 100
PG [mg/dl](30min) : 160
PG [mg/dl](60min) : 160
PG [mg/dl](90min) : 160
PG [mg/dl](120min) : 140
Insulin [microU/ml] (00min): 5
Insulin [microU/ml] (30min): 10
Insulin [microU/ml] (60min): 10
Insulin [microU/ml] (90min): 10
Insulin [microU/ml] (120min): 5

RESULTS
Matsuda Index: 12.34 (whole body insulin resistant: equal or lower than 2.5)
HOMA-IR(Matthews1985): 1.23 (normal: lower or equal to 1.6, liver insulin resistant: equal or more than 2.5.)
Insulinogenic Index: 0.08 (defect in insulin secretion: less than 0.4)
Disposition Index: 1.02 (product of insulinogenic index and Matsuda index: normal: more than 1)

HOME

http://mmatsuda.diabetes-smc.jp/MIndex.html

Summary

Euglycemic insulin clamp is a gold standard for the measurement of insulin resistance.
However, the method is not physiological.

HOMA is a good method to measure hepatic insulin resistance.

Matsuda index actually measures whole body insulin resistance including muscle contribution.
This OGTT-based measurement is physiological.

HOMA-IR cannot be used with SGLT-2 inhibitors. Matsuda index also needs correction by collecting urine sample after an OGTT.

1 in 11 adults have diabetes (415 million)

46.5% of adults with diabetes are undiagnosed

By 2040, **1 adult in 10** (642 million) will have diabetes

http://www.diabetesatlas.org/key-messages.html

http://www.idf.org/wdd-events/

idf.org

International Diabetes Federation

world diabetes day
14 November

Refine Search

KAWAGOE BLUE LIGHTING EVENT 2016

End Date: November 14, 2016

Location: Kawagoe Station, Kawagoe, Saitama Prefecture, Japan

Event Type: Blue Lighting

Event Description: Blue Light Up at the Kawagoe Station Bridge

Event Email: tokinokane-blue-lightup@diabetes-smc.jp

Google

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WDD 2016 around the world

106 events in 54 countries

Share your WDD 2016 activity

Share your own event information by completing the form here

World Diabetes Day is the world's largest diabetes awareness campaign.

http://tokinokane-blue-lightup.diabetes-smc.jp/forpc.html