Workshop Training Series

Metabolic Cages:

What data can we get and how to explain them?

Yongjun Wang Ph.D.

Director of Biomedical and Obesity Research Core

Nebraska Center for the Prevention of Obesity Diseases through Dietary Molecules

Metabolic Study Resource in BORC

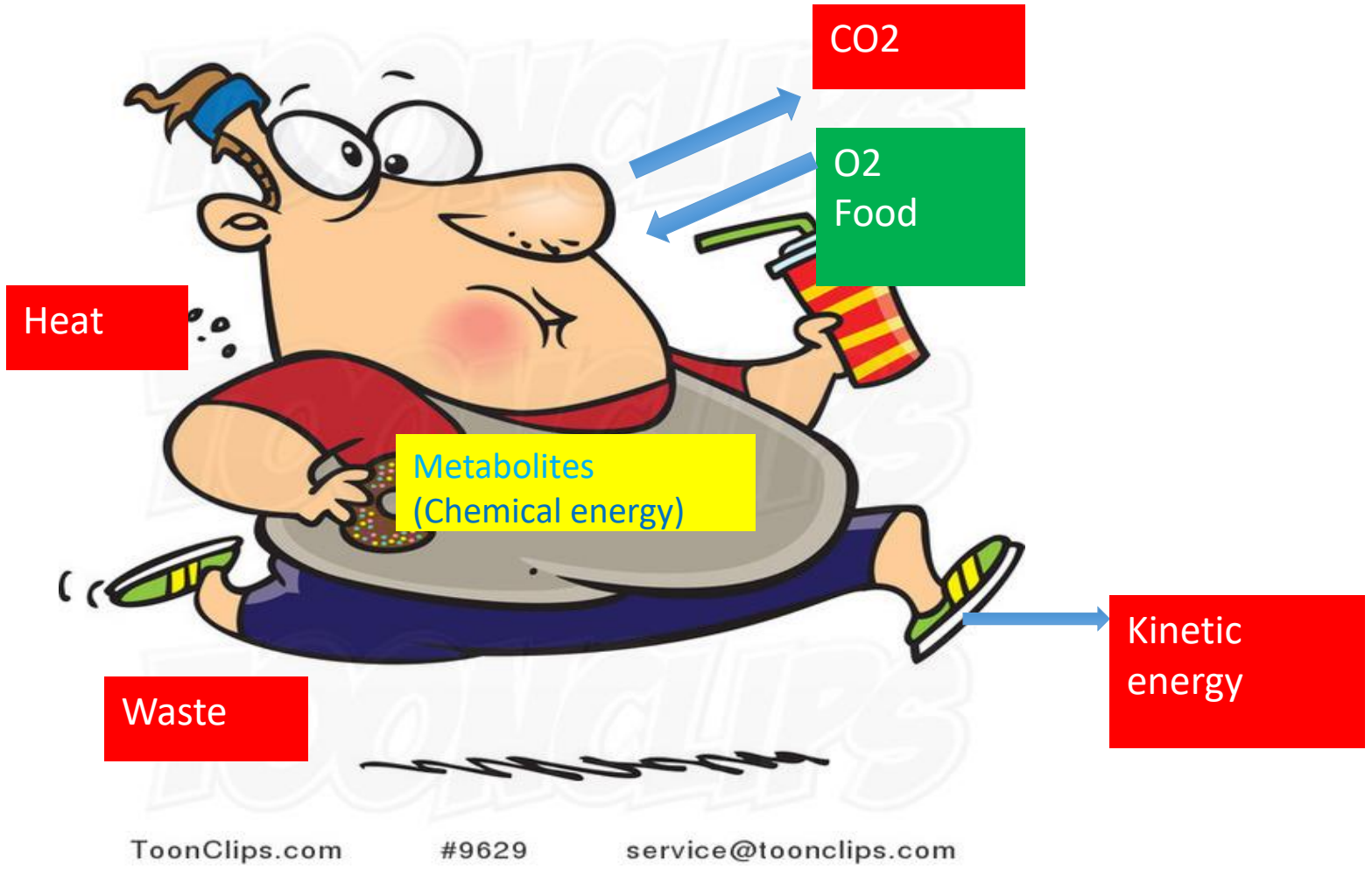
Metabolic cages (TSE Systems)

XFe-24 Extracellular Flux Analyzer

Vitros 250 Chemistry Analyzer

Agilent GC-MSD

Diet, Exercise and Metabolism



TSE PhenoMaster Metabolic Cages

A multi-modular platform that allows researchers to carry out metabolic, behavioral and physiological analysis of mice in an automated and synchronized manner. Currently our system has 12 cages with modules to measure metabolic performance, activity, as well as feeding and drinking behavior.

Indirect Gas Calorimetry

- Individual electronic mass flow controllers MFC for each cage (universal mice / rats)
- CO_2 sensor: Infrared spectroscopic differential
- O_2 sensor: Paramagnetic differential (high-speed)
- High-speed Peltier air drying unit.
- Fully Automated Gas Calibration: O_2 & CO_2

The Components Measured By The System

- Calorimetry
- Activity
- Drinking and feeding behavior

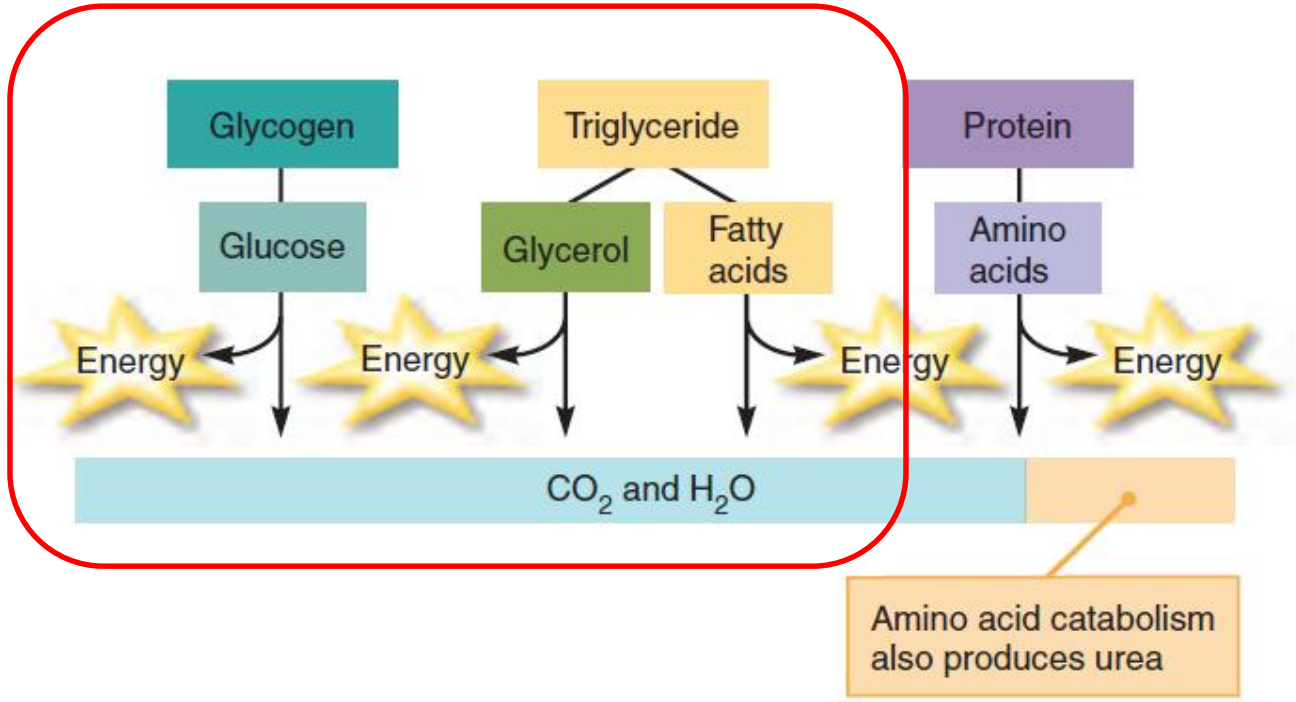
Calorimetry Results Parameter

Parameter	Description	Unit	Remarks
Flow	Flow	l/min	
Temp	Temperature	°C	Measurement in the box.
O2	Concentration	%	Reference and per box.
CO2	Concentration	%	Reference and per box.
dO2	Difference	%	Reference O2 - Box O2.
dCO2	Difference	%	Reference CO2 - Box CO2.
VO2	O2 consumption	ml/(kg x h) or ml/h	
VCO2	CO2 production	ml/(kg x h) or ml/h	
RER	Respiratory Exchange Rate		VCO2/VO2
H	Heat	kcal/(kg*h) or Kcal/h	Also possible in W/kg

Calorimetry Results Parameter

Parameter	Description
XT, YT	Breaks X-beam total (is equivalent to XA + XF) Breaks Y-beam total (is equivalent to YA + YF)
XF, YF	Breaks X-beam, fine movements Breaks Y-beam, fine movements
XA, YA	Breaks X-beam, ambulatory movements Breaks Y-beam, ambulatory movements
Z	Breaks Z-beam, rearing
Z2	Breaks Z2-beam, rearing
CenT, PerT	Sum central and peripheral ambulatory and fine movement
CenA, CenF	Central ambulatory and fine movement
PerA, PerF	Peripheral ambulatory and fine movement

The Major Source of Energy



The majority of proteins is used for biosynthesis of new proteins and accounts for a small proportion of energy source in normal physiological condition.

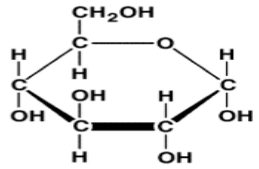
The Respiratory Exchange Ratio (RER)

- During **oxidation of nutrients** (oxidative phosphorylation) we convert food and **O_2** into **CO_2** and **energy.**
- The ratio between the amount of CO2 that is produced (VCO2) and the amount of O2 that is consumed (VO2) called the respiratory quotient (RQ) at cell level or respiratory exchange ration (RER) at body level.

RER (body) ~ RQ (cell)= VCO_2 / VO_2

Glucose, fructose, galactose

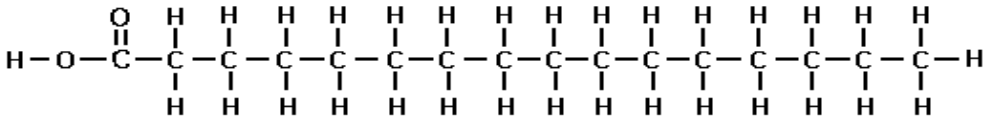
$C_6H_{12}O_6$



$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

$RQ = 6\ CO_2 / 6\ O_2 = 1.0$

Palmitic acid



$C_{16}H_{32}O_2 + 23\ O_2 \rightarrow 16\ CO_2 + 16\ H_2O$

$RQ= 16\ CO_2 / 23\ O_2 = 0.697$

RER is A Marker of Energy Source

- RQ = 1 for pure carbohydrates
- RQ = 0.7 for pure lipids

% Dietary Macronutrients Carbohydrates / Lipids	RQ (RER) mol CO_2 / mol O_2
100 / 0	1.00
80 / 20	0.88
60 / 40	0.80
40 / 60	0.76
20 / 80	0.73
0 / 100	0.71

The Calculation of Heat

- 1 mol of glucose has an heat of combustion (ΔH) -2,805 kJ, needs 6 mol oxygen.
- 1 mol of palmitate has an heat of combustion (ΔH) -9958 kJ needs 23 mol oxygen
- 1 liter of Oxygen = 0.044 mol
- For every **liter oxygen, the body makes about 20 kJ available for metabolism** (Glucose: 2805/6*0.044=20.6, Palmitate: 9958/23*0.044=19.1).

Diet composition carbohydrates / lipids (%)	Energy per liter oxygen (kJ l O_2^{-1})	Energy per liter oxygen (kcal l O_2^{-1})
100 / 0	21.3	5.09
80 / 20	20.6	4.92
60 / 40	20.2	4.82
40 / 60	20.0	4.78
20 / 80	19.8	4.73
0 / 100	19.7	4.71

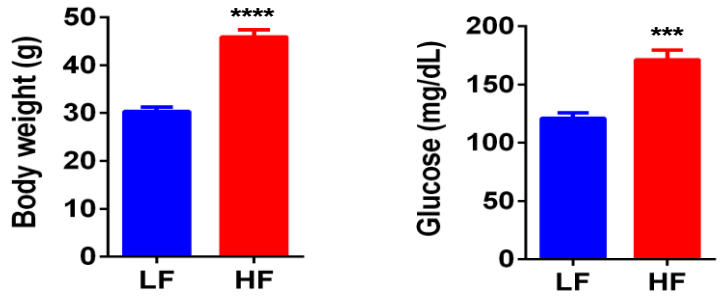
Using TSE system for metabolic cages

Animal information

Mice were fed with 10% fat or 45% fat for 16 weeks

- Low fat diet-fed mice: Lard 10% of total calories
- High fat diet-fed mice: Lard 45% of total calories

Body weight and glucose level

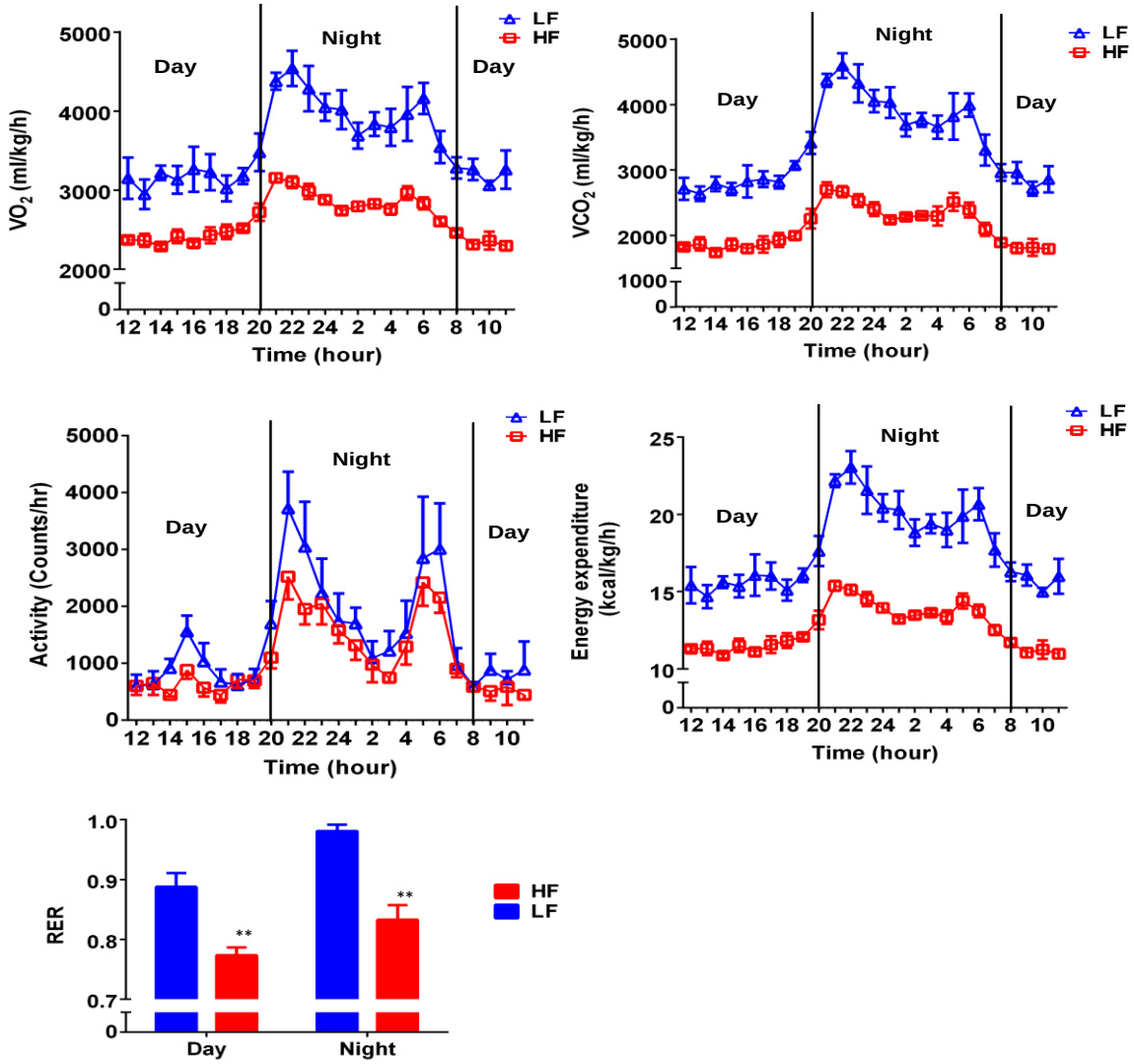


Statistical analysis

The two-tailed Student's t -test were used for statistical analyses of two-group comparisons.

All statistical analyses were performed using GraphPad Prism 6 (version 6.02).

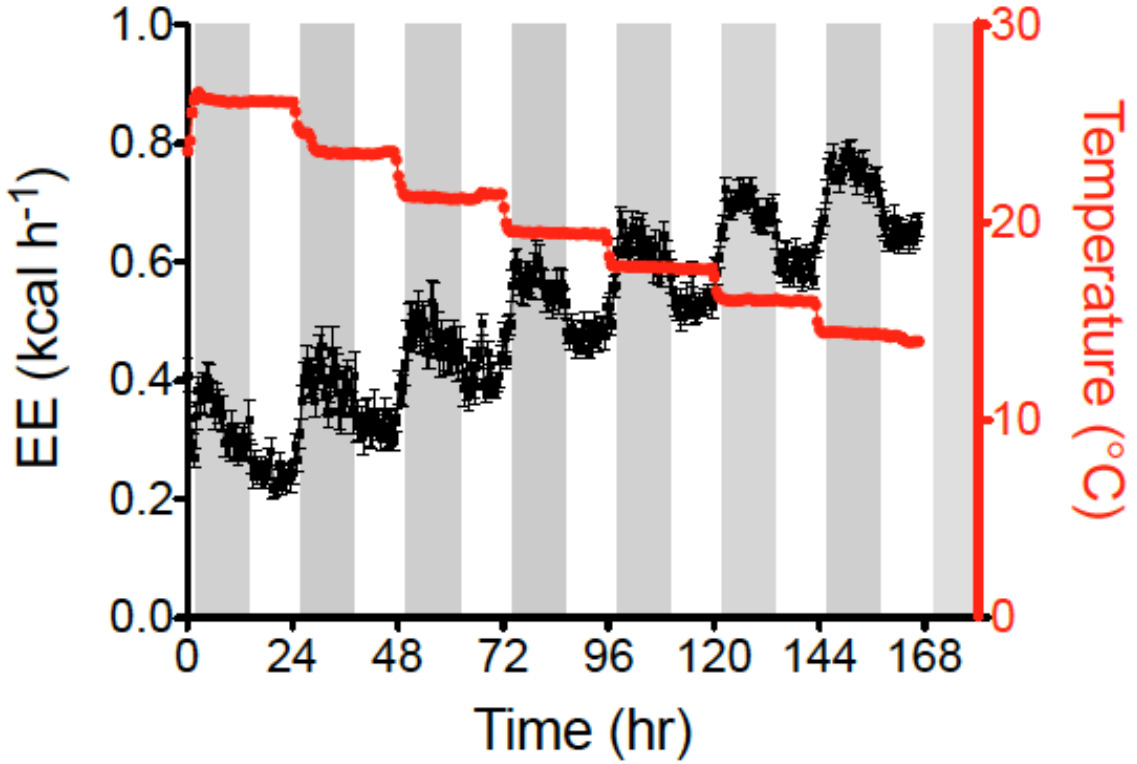
Data analysis from TSE system



Chung lab. By Yongeun Kim

Parameters affecting energy expenditure

- Environmental temperature



➢ Energy expenditure increases with decreasing environmental temperature

Parameters Affecting Energy Expenditure

- Genetic impacts
- Circadian rhythm
- Locomotor activity
- Group size (thermal conduction)
- Food intake (thermic effect of food)
- Body weight
- Body composition (muscles)
- Body size (Bergman’s rule)
- Environmental temperature

Thank you!