Practical implementation of personalized nutrition goals

We all have our own nutritional needs because we are different in so many ways. Gender, age, body size, physical activity, genomic variation, gut microbiome and other factors determine how much of each of the more than forty essential nutrients we need, what other food ingredients work for us, and whether we will develop food intolerances or allergies.

The advent of affordable large-scale genotyping, in particular, provides opportunities to predict the likely response of individuals to specific nutrition exposures. For example, two copies of a common variant in the MTHFR gene increases average folate requirements, and a variant in APOA2 makes saturated fat obesogenic in most homozygous carriers. There is an increasing number of such interactions that are firmly established and need to inform daily practice.

The greatest challenge for current nutrition practice is to translate the wealth of pertinent knowledge into actionable information. First, we need to estimate individual targets for all the different relevant nutrients, food types and behaviors. Whether this is done in the head, on a piece of paper, or by a computer, a large number of specific rules need to be applied to come up with discrete numbers and acceptable ranges for each target. The second step is even harder because it requires to come up with a good number of specific food combinations that meet all the important targets. Each food in these combinations also must be free of unwanted components, such as gluten, lactose, specific allergens, or just individually disliked foods, such as meats in general, pork specifically, or maybe spinach. Until now, meal plans have not been fully tailored to individual needs because it could not be done.

An innovative online platform now provides the much needed decision support for individual food choices. A rules engine first calculates targets, acceptable ranges and weighting factors for intake of total energy, nutrients of interest and food groups. The user can authorize temporary access to the personal genetic data just for the calculations without storing this sensitive information. All rules are listed to maintain full transparency. The calculated parameters are then used by a search engine to find meal plans that fit individual needs. The search takes into account individual food sensitivities and preferences. The system offers matching combinations, which the user can modify further within the constraints of individual needs and preferences.

Prof. Martin Kohlmeier, University of North Carolina

Martin Kohlmeier, currently professor of nutrition at the University of North Carolina at Chapel Hill, heads Nutrition in Medicine, and the Nutrigenetics Laboratory at the UNC Nutrition Research Institute. He investigates inherited variation as a modulator of nutrient disposition and develops online tools for genotype-specific nutrition guidance.

He completed medical school and received a medical doctorate on computational biochemistry from Heidelberg University, Germany. He received postdoctoral training in biochemistry and bioinformatics at the Max-Planck-Institute for Nutrition, Dortmund, Germany, and was awarded an advanced doctorate (Dr.med.habil.) in clinical biochemistry from the Freie Universität, Berlin. A significant part of his professional training concerned the molecular analysis and clinical treatment of people with inherited metabolic diseases.

Practical implementation of personalized nutrition goals

Martin Kohlmeier, MD, PhD
University of North Carolina at Chapel Hill
Department of Nutrition
and
UNC Nutrition Research Institute
mkohlmeier@unc.edu

Outline

Factors influencing nutritional needs

Nutritional genetics

Setting individual nutrition targets

Translating targets into practice

Decision support for food choices

Why personalized nutrition

Different people have different nutritional needs

Why personalized nutrition

Dietary Reference Intakes (DRIs): Recommended Dietary Allowances
Food and Nutrition Board, Institute of Medicine, National Academies

Life Stage Group	Calcium (mg/d)	Chromium (µg/d)	Copper (µg/d)	Fluoride (mg/d)	Iodine (µg/d)	Iron (mg/d)	Magnesium (mg/d)
Infants							
0 to 6 mo	200*	0.2*	200*	0.01*	110*	0.27*	30*
6 to 12 mo	260*	5.5*	220*	0.5*	130*	11	75*
Children							
1–3 y	700	11*	340	0.7*	90	7	80
4–8 y	1,000	15*	440	1*	90	10	130
Males							
9–13 y	1,300	25*	700	2*	120	8	240
14–18 y	1,300	35*	890	3*	150	11	410
19–30 y	1,000	35*	900	4*	150	8	400
31–50 y	1,000	35*	900	4*	150	8	420
51–70 y	1,000	30*	900	4*	150	8	420
> 70 y	1,200	30*	900	4*	150	8	420
Females							
9–13 y	1,300	21*	700	2*	120	8	240
14–18 y	1,300	24*	890	3*	150	15	360
19–30 y	1,000	25*	900	3*	150	18	310
31–50 y	1,000	25*	900	3*	150	18	320
51–70 y	1,200	20*	900	3*	150	8	320
> 70 y	1,200	20*	900	3*	150	8	320
Pregnancy							
14–18 y	1,300	29*	1,000	3*	220	27	400
19–30 y	1,000	30*	1,000	3*	220	27	350
31–50 y	1,000	30*	1,000	3*	220	27	360
Lactation							
14–18 y	1,300	44*	1,300	3*	290	10	360
19–30 y	1,000	45*	1,300	3*	290	9	310
31–50 y	1,000	45*	1,300	3*	290	9	320

Why personalized nutrition

Smokers need extra nutrient amounts

Vitamin C +40%

Why personalized nutrition

Intolerances and Sensitivities

Lactose Intolerance
Gluten Sensitivity
Food Allergies
Additives

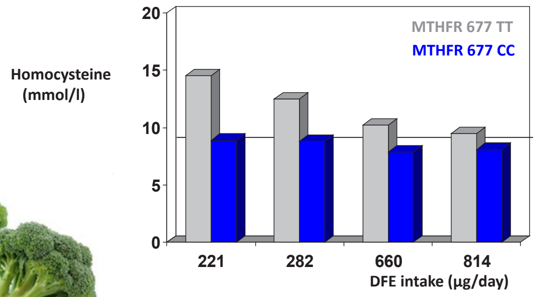
Why personalized nutrition

We must allow for consumer preferences:
Food dislikes
Flexitarian
Vegetarian
Vegan
Halal/Kosher
Low-carb
…

Genetic differences are important

Genetics

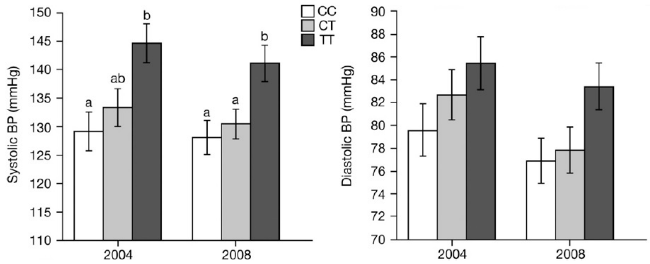
Folate intake versus homocysteine levels



Ashfield-Watt et al., 2002

Genetics

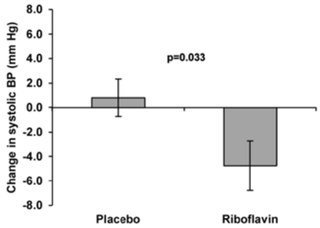
MTHFR-related blood pressure differences



Wilson CP et al., 2012

Genetics

Lowering BP with 1.6 mg riboflavin/day for 16-weeks

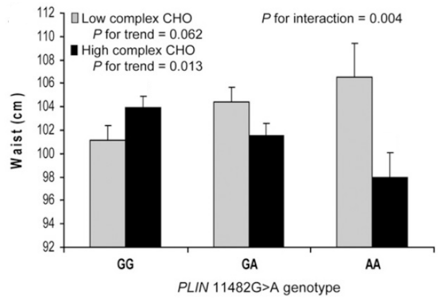


RCT in Ireland of treated hypertensive adults with MTHFR TT, achieving an average reduction of systolic BP by 5.6 mm Hg

Wilson CP et al., 2013

Genetics

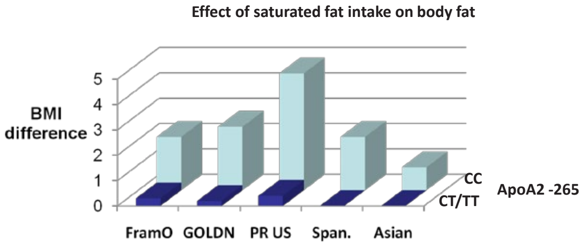
Genotype-specific response to carbohydrate



Smith CE et al., 2008

Genetics

Genotype-specific response to saturated fat



Genotype ApoA2 -265 CC frequency is about 15% in the US

Data from Corella et al.
Arch Int Med 2009;169:1897-1906
and Int J Obesity 2010;1-10

Genetics

Some genes for tailoring nutrition targets

IL6	ALOX5	AMY1	NAT1	TFAP2B
UCP1	COX2	GFOD2	NAT2	TNFA
UCP3	CETP	IRS1	GSTM1	LCT
FTO	FADS1	SIRT1	GSTP1	CA6
APOA2	FADS2	ESR2	UGT1A1	TAS1R1
PLIN	APOE	AGT	XPC	TAS1R2
CLOCK	ABCG5	ADD1	MGMT	TAS1R3
MC4R	ABCG8	GRK4	PON1	TAS2R3
PPARG	PNPLA3	SLC4A5	XRCC1	TAS2R4
ADRB2	DHCR7	DRD2	MPO	TAS2R5
ADRB3	GC	TMPRSS6	MTP	TAS2R19
FABP2	VDR	SLC40A1	MnSOD	TAS2R20
ADH1B	ALPL	HFE	GATA3	TAS2R38
ALDH2	FUT2	HAMP	OCT	TAS2R50
CYP1A2	TCN2	TRPM7	CASR	TAS2R60
ADORA2A	HP	CUBN	PAPOLG	OR2M7
MTHFR	CYP4F2	SLC23A1	CFTR	OR10A2
DHFR	F2	SLC23A2	TCF7L2	CD36
MTHFD1	F5	PLA2G4A	SCARB1	FGF21
PEMT	BCMO1	SEPP1	SLC30A3	HTR2A

Genetics

A brief digression about nutrigenetic harms

Such harms are mostly related to

- Expenditures and opportunity costs
- Misguided use of risky therapies
- Psychological and social burdens
- Insurance and employment risks

Genetics

Utility of genetic information

In how many cases is the outcome better with the information than without it?

Low harm levels leave room for net benefits.

harms vs benefits

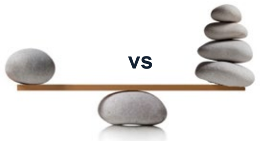
Genetics

Utility of genetic information

In how many cases is the outcome better with the information than without it?

Greater harm makes nutrigenetics useless.

harms vs benefits



Nutrition Choices

Nutrition choices

How much do they need and from which foods?

Anna
female 27 y
158 cm, 48 kg
BP 100/70
running 40 mins/d
non-smoker
vegetarian
gluten-sensitive

MTHFR 677 TT
UCP1 rs1800592 CT
TAS1R2 rs3935570 GG

Ben
male 56 y
182 cm, 96 kg
BP 140/90
sedentary
smoker
omnivore
lactose-intolerant

APOA2 -265 CC
CYP1A2 -3860AA
GC rs2282679 GG

Nutrition choices

Assessment → Targets → Planning

Nutrition choices

Assessment → Targets

Assessment
- Age
- Gender
- Weight
- Height
- Exercise
- Conditions
- Medications
- Personal goals
- Preferences
- Cultural settings
- ….
- Genetics

Targets
- Dietary patterns
- Food groups
- Macronutrients
- Fats
- Minerals
- Micronutrients
- Bioactives

Nutrition choices

A comprehensive online tool for personal decision support

Calculates nutrition targets based personal information (age/gender, physical activity, lifestyle, risk factors, genetics, ...)

The platform handles numerous concurrent rules and can accommodate an ever-growing number of algorithms

Compatible with most browsers for computers, smart phones and other mobile devices

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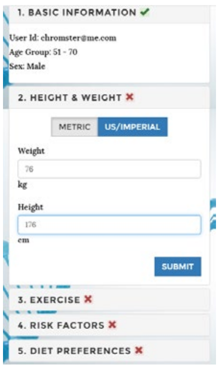
Nutrition choices

This tool calculates targets even with only partial input



Nutrient	Personalized
Calories	2121.0 kcal
Protein	68.0 g
Saturated Fat	< 24.0 g
Cholesterol	< 290.0 mg
Folate	387.0 µg
Added Folate	< 387.0 µg
Vitamin C	87.0 mg
Iron	8.0 mg
Sodium	< 2223.0 mg
Calcium	966.0 mg
Magnesium	406.0 mg
Red Meat	< 97.0 g
Fruits/Veggies	> 580.0 g
Vitamin A	2899.0 IU
Preformed Vit. A	< 2899.0 IU

Nutrition choices

How much do they need?

Anna
female 27 y
158 cm, 48 kg
BP 100/70
running 40 mins/d
non-smoker
vegetarian
gluten-sensitive

MTHFR 677 TT
UCP1 rs1800592 CT
TAS1R2 rs3935570 GG

Nutrient	per day	Comment: Extra protein?
Energy	1760 kcal *	1825 kcal for BMI 22
Protein	38.4 g	Based on 0.8 g/kg
Total fat	59 g	Based on 30% of total energy
Saturated fat	<20 g	Based on < 10% of total energy
Carbohydrate	270 g	
Sugars	<27 g *	Avoid overeating sugar
Sodium	<2300 mg	More with sweating
Calcium	1000 mg	
Magnesium	>335 mg	
Iron	18 mg	
Folate	>600 µg *	
Riboflavin	> 2.2 mg *	
Vitamin C	>75 mg	
Vitamin D	>600 IU	

Nutrition choices

How much do they need?

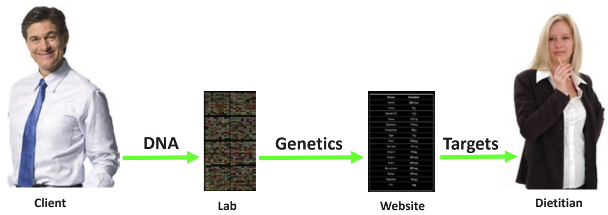
Ben
male 56 y
182 cm, 96 kg
BP 140/90
sedentary
smoker
omnivore
lactose-intolerant

APOA2 -265 CC
CYP1A2 -3860AA
GC rs2282679 GG

Nutrient	per day	Comment: Caffeine<200 mg
Energy	2638 kcal	Start exercising
Protein	76.8 g	Based on 0.8 g/kg
Total fat	88 g	Based on 30% of total energy
Saturated fat	<13 g *	
Carbohydrate	385 g	
Sugars	<39 g	
Sodium	<1600 mg	Carefully avoid getting more
Calcium	1000 mg	
Magnesium	>420 mg	
Iron	8 mg	
Folate	>400 µg	
Riboflavin	> 1.3 mg	
Vitamin C	>126 mg	
Vitamin D	>900 IU *	

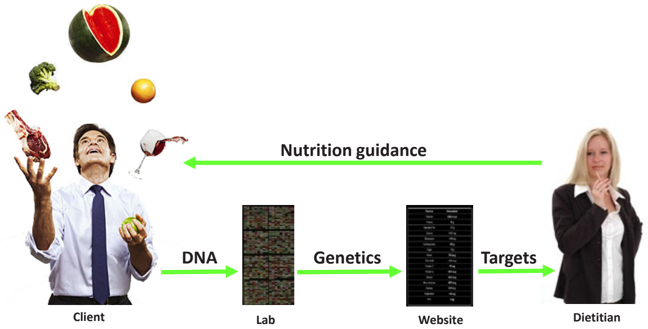
Nutrition choices

So far, so good, now they know the targets



Nutrition choices

This is the difficult part: making food choices



Nutrition choices

Assessment → **Targets** → **Planning**

Assessment	Targets	Planning
Age Gender Weight Height Exercise Conditions Medications Personal goals Preferences Cultural setting …. Genetics	Dietary patterns Food groups Macronutrients Fats Minerals Micronutrients Bioactives	Behavioral Change (limit snacking) General guidelines (eat more vegetables) Specific directions (limit to 1 cup of coffee) Meal plans and tips Dietary supplements (300 IU Vitamin E)

Nutrition choices

Tell Anna and Ben what to do based on their targets

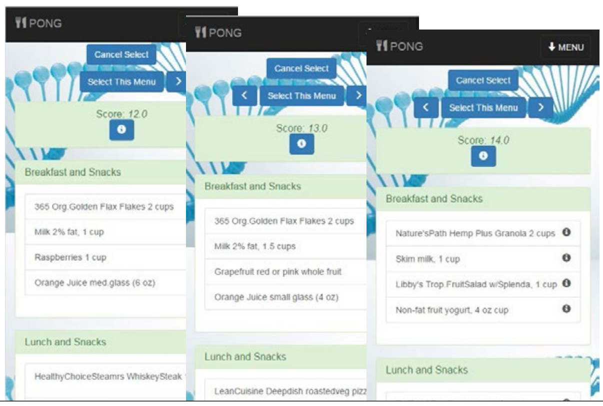
Nutrient	per day
Energy	1760 kcal
Protein	38.4 g
Total fat	59 g
Saturated fat	<20 g
Carbohydrate	264 g
Sugars	<26 g
Sodium	<2300 mg
Calcium	1000 mg
Magnesium	>335 mg
Iron	18 mg
Folate	>600 µg
Riboflavin	> 2.2 mg
Vitamin C	>75 mg
Vitamin D	>600 IU
Vegetarian	Gluten-free

Nutrient	per day
Energy	2638 kcal
Protein	76.8 g
Total fat	88 g
Saturated fat	<13 g
Carbohydrate	396 g
Sugars	<40 g
Sodium	<1600 mg
Calcium	1000 mg
Magnesium	>420 mg
Iron	8 mg
Folate	>400 µg
Riboflavin	> 1.3 mg
Vitamin C	>126 mg
Vitamin D	>900 IU
Caffeine <200mg	Low lactose

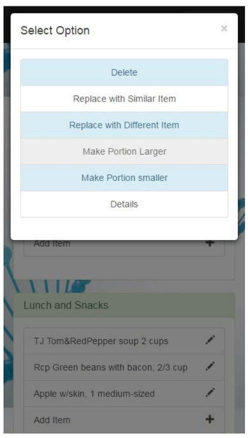
This is too complex, we need decision support

Decision support

The PONG tool offers individually tailored meal plans



Decision support



The user can then further modify these meal plans

Decision support

Nutritional Info for 3 Meals

Nutrient	Actual	Target
Calories	**2095.0 kcal**	2121.0 kcal
Protein	**75.5 g**	68.0 g
Saturated Fat	**14.2 g**	< 24.0 g
Cholesterol	**78.0 mg**	< 290.0 mg
Folate	**378.0 µg**	387.0 µg
Added Folate	**208.0 µg**	< 387.0 µg
Vitamin C	**120.0 mg**	87.0 mg
Iron	**18.1 mg**	8.0 mg
Sodium	**1956.0 mg**	< 2223.0 mg
Calcium	**1037.0 mg**	966.0 mg
Magnesium	**399.0 mg**	406.0 mg
Red Meat	**85.0 g**	< 97.0 g
Fruits/Veggies	**665.0 g**	> 580.0 g
Vitamin A	**2699.0 IU**	2899.0 IU
Preformed Vit. A	**513.0 IU**	< 2899.0 IU
Beta-Carotene	**2183.0 IU**	> 1691.0 IU

Displays comprehensive nutrient information

Decision support

Nutritional Information

Rcp Green beans with bacon, 2/3 cup

just good

Nutrient	Value
Calories	**46.0 kcal**
Protein	**2.5 g**
Saturated Fat	**0.8 g**
Cholesterol	**2.0 mg**
Folate	**37.0 µg**
Added Folate	**0.0 µg**
Vitamin C	**16.0 mg**
Iron	**1.1 mg**
Sodium	**93.0 mg**
Calcium	**38.0 mg**
Magnesium	**58.0 mg**
Red Meat	**8.0 g**
Fruits/Veggies	**90 g**
Vitamin A	**734.0 IU**
Preformed Vit. A	**6.0 IU**
Beta-Carotene	**728.0 IU**

Decision support

Calculating goodness-of-fit for meal plans

- **Determine how much each criterion of a daily meal plan deviates from the intended targets.**
- **Use the individually appropriate distance functions to determine the point value Δ for each deviation.**
- **Apply nutrient-/food-specific weights to the point values for each target.**
- **Add up all weighted point values to get a single score reflecting the goodness-of-fit of the meal plan.**
- **The lower the score, the better the fit.**

Decision support

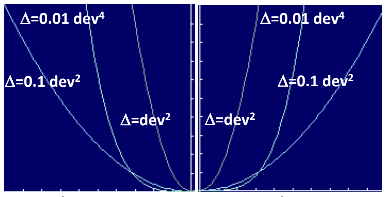
The distance functions

dev = intake-target

The parabolic functions increasingly penalize the deviations (dev) the farther the intake strays from the intended target.

The exponents and constants determine how heavily deviations are penalized.

Function form and parameters can be distinct for negative and positive deviations from the target, targeted nutrient or food group, and user type.



intake < target **intake > target**

Score = $\Delta_{nut1} * wt_1 + \Delta_{nut2} * wt_2 + ...$

Conclusions

Our daily food choices strongly impact overall wellbeing and survival

Current guidelines already recommend very different nutrient amounts for different people

The evidence for genotype-specific nutrition needs already implicates dozens of genetic variants

The complexity of navigating dietary needs has become so great that we need practical decision support tools

Thanks to all my collaborators!

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Questions?