



Methods to measure diet & the link between diet, nutrition & type 2 diabetes

2nd April, CDS2019 Nita Forouhi MRC Epidemiology Unit, Cambridge

Learning objectives: to gain understanding of

- the methods and tools that can be used to assess dietary intakes
- dietary factors that are associated with T2D risk
 - cutting through dietary controversies



"Diet" has multiple components & dimensions



Measuring diet- which method? - fit for purpose

Doubly-labelled water	Objective Meas	ure		
Biochemical markers	3			
Duplicate diets; di Weighed food r Diet	rect observation ecords histories	Subjective measure (self-reported, reported by	others)	
	Food diaries			
	24-hour r	ecall		
	Foo	d frequency questionnaire		
		Household record Inventory method	House	hold level
		Food account me	ethod	
		List-recall F	method	Population level

Ease of Assessment

Dietary Assessment



Commonest subjective methods

- Frequency of foods eaten habitually
- Recall foods & portions from past 24 hours
- Collection of diet data at the moment of consumption

FFQ









Food Frequency Questionnaire

- Used for capturing differences in habitual diet between groups of people over a long period of time
- □ Is relatively quick to do; inexpensive
- Predefined list of foods
 - What foods? How many?
 - How often?
 - (quantity?/composition?)

Reporting of foods: FFQ



PLEASE PUT A TICK (1) ON EVERY LINE

FOODS AND AMOUNTS	AVERAGE L	JSE LAS	ST YEA	R					
SWEETS AND SNACKS (medium serving)	Never or less than once/month	1-3 per month	Once a week	2-4 per week	5-6 per week	Once a day	2-3 per day	4-5 per day	6+ per day
Sweet biscuits, chocolate , eg. digestive (one)	~								
Sweet biscuits, plain, eg. Nice, ginger (one)									
Cakes eg. fruit, sponge, home baked									
Cakes eg. fruit, sponge, ready made	1								2
Buns, pastries eg. scones, flapjacks, home baked									
Buns, pastries eg. croissants, doughnuts, ready made			- 10 - 10 - 10 - 10 - 10 - 10 - 10 - 10						
Fruit pies, tarts, crumbles, home baked									
Fruit pies, tarts, crumbles, ready made	1								
Sponge puddings, home baked	1								
Sponge puddings, ready made	1								
Milk puddings, eg. rice, custard, trifle									\checkmark
Ice cream, choc ices				V					
mRt mtetreu niesdaren eganen -	1941년 아카이 영화								

FOODS AND AMOUNTS	AVERAGE USE LAST YEAR									
DRINKS	Never or less than once/month	1-3 per month	Once a week	2-4 per week	5-6 per week	Once a day	2-3 per day	4-5 per day	6+ per day	
Tea (cup)								V		
Coffee, instant or ground (cup)						V				
Coffee, decaffeinated (cup)	\checkmark			*C						
Coffee whitener, eg. Coffee-mate (teaspoon)	\checkmark									
Cocoa, hot chocolate (cup)						\checkmark				
Horlicks, Ovaltine (cup)	V							1100		
Wine (glass)	\checkmark									
Beer, lager or cider (half pint)	V.								1	
Port, sherry, vermouth, liqueurs (glass)	V.			I						
Spirits, eg. gin, brandy, whisky, vodka (single)	V.									
Low calorie or diet fizzy soft drinks (glass)	\sim					-				
Fizzy soft drinks, eg. Coca cola, lemonade (glass)						1		1		
Pure fruit juice (100%) eg. orange, apple juice (glass)	\checkmark									
Fruit squash or cordial (glass)	1000						V			

Apples				~					
Pears				~					
Oranges, satsumas, mandarins		~							
Grapefruit									
Bananas			V.						
Grapes			\checkmark						
Melon	\checkmark								
Peaches, plums, apricots				V					
Strawberries, raspberries, kiwi fruit						V			
Tinned fruit		\checkmark		-					
Dried fruit, eg. raisins, prunes	V								
	Never or less than once/month	1-3 per month	Once a week	2-4 per week	5-6 per week	Once a day	2-3 per day	4-5 per day	6+ per day

Please check that you have a tick (1) on EVERY line

Example page of the EPIC FFQ

Notice the complicated structure of frequency & seasonal availability

24h Diet Recall

Recollection of all foods & drinks consumed in past 24h

- From waking to sleeping; or
- From first eating till last eating; or
- From midnight to midnight
- Interview vs. self-administered
- □ Face-to-face vs. telephone
- Interview techniques: probing, but non-judgemental
- Knowledge of interviewer about: food preparation, product availability (brands)
- Accuracy is improved by multiple (preferably) nonconsecutive recalls

1. Plea	se enter today's	date:						13	108	19
								Day	Month	Ye
2. Which	ch day of the we	ek does thi	is record?	Please ti	ick gne:				10.0	
Sun	Mon	Tues	Weds	Thurs	V Fri		Sat		18 AUG	1995
										1
3. Is thi	is a typical day?	Please ticl	k one:						Yes	No
If no	t, give an examp	ole of a typi	ical day al	fter vester	day's re	cord,	if you	wish.		
				the second s						
					15753	1231				032
24 HOUF	RECORD	1.0034				231				1932
24 HOUF Time	R RECORD Quantity eaten	Detai	ils of food a	nd drink						
24 HOUF Time 7 ISam	Quantity eaten	Detai T.e.	ils of food a	nd drink						
24 HOUF Time Y ISam	R RECORD Quantity eaten	Detai T.e. Seu	ils of food a Mi Skii	nd drink	ien					
24 HOUF Time Y ISam	RECORD Quantity eaten 1 Cup 1 Lup	Detai T.e. Sei ns Wt	ils of food a mi Skii nite S	nd drink www.d M	ien					
24 HOUF Time Y ISam	RECORD Quantity eaten 1 Cup 15 teaspoor 1 hauge fruit	Detai Te Sei Nish R	ils of food a ni Skii hite S lice Cri	nd drink mud M ugar	ien + Slio	ed l	xana	wa.		
24 HOUF Time Y ISam	RECORD Quantity eaten I Cup I's teaspoor I hauge Truit I 2 teaspoor	Detai Te Sei Na Wt Dish R	ils of food a ni Skii hite S lice Cri vlite	nd drink mud M ugar spies Suga	ien + Slio	ed l	xana	wa		
24 HOUF Time YISam	RECORD Quantity eaten I Cup I's teaspoor I haygetnut 2 teaspoor	Detai Te Sei Ns Wt Dish R Se	ils of food a ni Skin hite S lice Cri vlite vlite mi S	nd drink mud M ugar Suga Kintu	ien + Slio r ed M	iek	xua	wa		

Example of an EPIC 24hr Diet Recall

The 24h DRs in EPIC were self-administered

24h DR – portion estimation

- Household measures (cups, bowls, spoons etc)
- Ruler
- In handfuls
- Photographs
- Food models
- Description by the participant in brand-specific / product-specific sizes
- Weighed

Food Photographs



Diet/Food Records

'diaries'



Food record

- Record at time of consumption not by memory
- Training/explanation necessary
- Using portion estimation tools similar to 24h DR
- Might change participant's diet

'Train your participant'

'the husband'

'the wife'

	EVENING MEAL	
Food/Drink	Description and Preparation	Amount
PILY BRK REDE PEPPERS PRIANJER WITTH AS CASHEW NO RICE & GAN JOSH JOSH ATER FRUIT	MINCED BORK CHOPPED TO THITE WHITE BOILED SPICES TAL BAACK BERRIES SMINISBURY'S VANIMA	9B 1 TAREAS POON K DO2. 8B 1 Pr. 17A 2 SCOOPS
	TER EVENING to be bet bins at	Jaké

	EVENING MEAL	- 5 M D
Food/Drink	Description and Preparation	Amount
spicy Pork rates + shredded abbage	Pork red pepper. Sulvanas, aprico cashew nuts corrander pice teorian Join spice teorian Join spice	ЧЬ. Б
Juice	Samobury pure orange juice frem concentrate	sml glass.
	ATER EVENING - up to last thing at r	light

Variation in consumption by day of week



EPIC-Norfolk Study, UK

Comparison with FFQ

24h Diet Recall, or food record

- Collection of actually consumed foods & their quantity
- 🗆 Data: absolute
- Open ended capture diversity
- More expensive
- Takes longer (esp record)

FFQ

- Collection of
 - participant's perception of "habitual" food intake
- Data: relative (ranking)
- Set number of questions
- Less expensive
- Takes short time

Challenge: Measurement error; validity

There will always be error in dietary assessments. The challenge is to understand, estimate, and make use of the error structure during analysis



This Photo by Unknown Author is licensed under CC BY-NC-ND

Challenge: Bias

Obtain the data as accurately as possible by managing recall & social desirability bias



Challenge: Food Composition Databases

- Relevant to target population
 - e.g. For a study in India;
 use database specific to India
 - Soil/climate
 - Food fortification
 - Traditional foods
 - Manufactured foods
- Coverage of foods and drinks
- Coverage of nutrients
- Missing values
- □ Up-to-date ?

http://www.fao.org/fileadmin/templates/food_compositio n/images/FCD.pdf



Dietary Assessment Technologies



Existing automated tools

Research and surveillance

asa24.nci.nih.gov/

ASA24





intake24.co.uk/





Consumer use











Objective measurement using nutritional biomarkers

- Biological markers in biological specimens such as blood or urine that reflect intake sufficiently closely to act as objective indices of true intake
- Biomarkers of intake vs status



Nutritional biomarker: plasma vitamin C as a marker of fruit & vegetable intake



Harding, Forouhi et al, Archives of Internal Medicine 2008

Nutritional biomarker: Is sugar intake related to obesity?



'True' sugareintation tende asugardinvaithe biomarker

Quintiles

Bingham S 2007

Appropriate assessment methods: DAPA toolkit www.measurement-toolkit.org https://www.nutritools.org/



https://dietassessmentprimer.cancer.gov/

Welcome to the Diet, Anthropometry and Physical Activity (DAPA) Measurement Toolkit.

The DAPA Measurement Toolkit is a free web-based resource to assist researchers and public health or public end-users to identify methods for the assessment of diet, anthropometry and physical activity.

The toolkit does not recommend or promote any specific method or instrument, but rather provides information for end-users to be better equipped at using and interpreting existing data or reaching an appropriate decision on choosing methods that are fit-for purpose when planning new studies.

Dietary Assessment



Physical Activity Assessment







Diet & health: Dietary guidelines







Public Health England



A Quick Guide to the Government's Healthy Eating Recommendations

Nutrition Therapy Recommendations for the Management of Adults With Diabetes



Popular dietary "guidelines"



Dietary priorities: from controversy to consensus



- Weight control
 - What is the best diet?
- Nutrients vs. foods
 - Fats / Carbohydrates
 - Food groups



"Diet" has hundreds of components – this lecture cannot cover every dietary factor

#1. Weight/obesity: calorie control



Energy (calorie) restriction works...





Food makers told to cut calories by 20% by 2024

Public Health England says the target would slash costs to the NHS by £4.5bn and prevent more than 35,000 premature deaths

Primary care-led weight management for remission of type 2 diabetes (DiRECT): an open-label, cluster-randomised trial

Lean M. The Lancet, 2017

В А For Odds ratio 19.7, 95% CI 7.8-49.8; 100-Fisher's exact p<0.0001 100p<0.0001 Proportion achieving ≥15 kg weight loss at 12 months (%) remission of T2D Proportion achieving remission 80-80at 12 months (%) 60-60-46% 40 40-24% 20-20-4% 0% 0-0 Control Control Intervention Intervention group group group group С 100 Odds ratio per kg weight loss 1.32, 95% Cl 1.23–1.41; p<0.0001 86% Proportion achieving remission at 12 months (%) 80-57% 60-40. 34% 20-7% 0% 0 0 <5 5-10 10-15 ≥15

Weight loss at 12 months (kg)

Weight loss puts Type 2 diabetes into remission for at least two years THE LANCET

Published on: 6 March 2019

Diabetes & Endocrinology

More than a third of people with Type 2 diabetes who took part in a weight management programme delivered by the NHS through GP surgeries remain free of diabetes two years later.

> ⁶ These results further challenge the perception that Type 2 diabetes needs to be a lifelong condition for everyone diagnosed with it.

Effect of low-fat diet interventions versus other diet interventions on long-term weight change in adults: a systematic review and meta-analysis

#2. Weight loss: Which diet?

53 RCTs; n=68,128

Low-fat vs low-carbohydrate intervention



Tobias DK et al; Lancet DE, 2015
Which diet works best for weight loss?



Johnston B, JAMA 2014

Diet, obesity, T2D: complex influences in the long-term



#3. Foods and development of T2D



Summary of meta-analyses of prospective cohort studies on food and beverage intake and type 2 diabetes Ley SH et al Lancet 2014

+ Overall dietary patterns

MRC | Medical Research Council



- EPIC-InterAct
- Nested case-cohort study within EPIC Europe
- Large N=340,234 at baseline
 12,403 incident cases of T2D
- Long follow-up3.99 million person years
- •Data on diet FFQ
- Exposure heterogeneity



Diabetologia (2011) 54:2272–2282 DOI 10.1007/s00125-011-2182-9

ARTICLE

Design and cohort description of the InterAct Project: an examination of the interaction of genetic and lifestyle factors on the incidence of type 2 diabetes in the EPIC Study



Langenberg C et al, Diabetologia 2011



Diabetologia (2013) 56:1520–1530 DOI 10.1007/s00125-013-2899-8

ARTICLE

Consumption of sweet beverages and type 2 diabetes incidence in European adults: results from EPIC-InterAct

The InterAct consortium





T2D associated with one serving [336g (12 oz)] change in the consumption of types of sweet beverages: HR & 95% CI



Sugary drinks: probing deeper - 7-day diary data

ARTICLE

Diabetologia 2015

Prospective associations and population impact of sweet beverage intake and type 2 diabetes, and effects of substitutions with alternative beverages

Laura O'Connor¹ • Fumiaki Imamura¹ • Marleen A. H. Lentjes² • Kay-Tee Khaw² • Nicholas J. Wareham¹ • Nita G. Forouhi¹

- Wider variety of drinks
 - Soft drinks, ASB, fruit juice
 - Sweetened & unsweetened tea, coffee
 - Sweetened milky drinks



• How does **substituting alternative beverages** for sweet beverages influence future T2D? Consumption of sugar sweetened beverages, artificially sweetened beverages, and fruit juice and incidence of type 2 diabetes: systematic review, meta-analysis, and estimation of population attributable fraction

Fumiaki Imamura,¹ Laura O'Connor,¹ Zheng Ye,¹ Jaakko Mursu,² Yasuaki Hayashino,^{3, 4} Shilpa N Bhupathiraju,⁵ Nita G Forouhi¹

17 cohorts; >10m person years; 38,253 T2D cases SSB -> T2D risk; ASB/FJ – not optimal alternatives

SSB 8-10% (2m) T2D cases in USA; 3-5% (0.8m) in UK



2015

BM

Convinced by the evidence?



Soft drinks industry criticises Cambridge sugar study for 'masquerading' as academic

by Sara Spary, 22.07.2015

"Gavin Partington, director general of the British Soft Drinks Association, said: 'This is a health campaign statement masquerading as an academic study..."



- The average intake across the UK population of free sugars should not exceed 5% of total dietary energy intake for age groups from 2 years upwards
- The consumption of sugar-sweetened drinks should be minimised in children and adults

GLOBAL REPORT ON **DIABETES**

2016



Diabetologia, 2013

Association between dietary meat consumption and incident type 2 diabetes: the EPIC-InterAct study



Habitual intake; adjusted analyses







Total dairy products Comparison of highest vs. lowest fifths of intake (g/d)



Model 3: Adjusted for centre, age at recruitment, sex, BMI, educational level, smoking status, physical activity level, alcohol intake, intake of energy and energy adjusted intake of fruits plus vegetables, red meat, processed meat, sugar-sweetened soft drinks, coffee, cereals, and cereal products.

Dairy products and T2D





Combined fermented dairy products intake

#4. A closer look at nutrients: Fat intake

The great fat debate: SFA and T2D



Differences in the prospective association between individual plasma phospholipid saturated fatty acids and incident type 2 diabetes: the EPIC-InterAct case-cohort study

Nita G Forouhi, Albert Koulman, Stephen J Sharp, Fumiaki Imamura, Janine Kröger, Matthias B Schulze, Francesca L Crowe, José María Huerta, Marcela Guevara, Joline WJ Beulens, Geertruida J van Woudenbergh, Laura Wang, Keith Summerhill, Julian L Griffin, Edith JM Feskens, Pilar Amiano, Heiner Boeing, Françoise Clavel-Chapelon, Laureen Dartois, Guy Fagherazzi, Paul W Franks, Carlos Gonzalez, Marianne Uhre Jakobsen, Rudolf Kaaks, Timothy J Key, Kay-Tee Khaw, Tilman Kühn, Amalia Mattiello, Peter M Nilsson, Kim Overvad, Valeria Pala, Domenico Palli, J Ramón Quirós, Olov Rolandsson, Nina Roswall, Carlotta Sacerdote, María-José Sánchez, Nadia Slimani, Annemieke MW Spijkerman, Anne Tjonneland, Maria-José Tormo, Rosario Tumino, Daphne L van der A, Yvonne T van der Schouw, Claudia Langenberg, Elio Riboli, Nicholas J Wareham

Biomarkers

Lancet Diabetes Endocrinol 2014

Biomarkers: Plasma phospholipid saturated fatty acids & T2D



Fat is not just fat: not one homogeneous entity



LEARNING POINT:

1. Not all fat is the same Not all fat is "bad" There are "good" fats & "bad" fats *Type* of fat matters

2. Subtype of fat matters



3. What replaces fat in the diet matters: *Substitution analyses*

#5. Carbohydrates intake





Carbohydrates



Carb quality indicators

- Whole grain or refined
- Fibre
- Glycaemic response (GI, GL)
- Food structure: solid/liquid



GI = Glycaemic index GL = Glycaemic load

Carbohydrates and Health



Whole grain, fibre: important

OPEN O ACCESS Freely available online

PLOS MEDICINE

Whole Grain, Bran, and Germ Intake and Risk of Type 2 Diabetes: A Prospective Cohort Study and Systematic Review deMunter J; PLoS Med; 2007

Whole grain and refined grain consumption and the risk of type 2 diabetes: a systematic review and dose–response meta-analysis of cohort studies Aune D; Eur J Epidemiol 2013

META-ANALYSIS

Dietary fibre and incidence of type 2 diabetes in eight European countries: the EPIC-InterAct Study and a meta-analysis of prospective studies

Low-carb diets for T2D?

Huge interest; definitions vary greatly short duration trials

Carbohydrate quality matters

- Reduce refined carb foods
- Consume whole grain & high fibre foods

Choosing high quality carbs

- Whole grain stamp OR ingredients list
- Ratio of total carb to fibre
 - >10:1 = avoid
 - <10:1 = good choice</pre>
 - <5:1 = great choice (fewer options)



Carbohydrate status	Definition
Very low-carb ketogenic diet (VLCKD)	20–50 g/d or <10% of El
Low-carb	<130 g/d or <26% of El
Moderate-carb	26%–45% of El
High carb	>45% of EI

Feinman et al. / Nutrition 31 (2015)

Foods- more than the sum of the nutrient parts



"Food matrix"

Macronutrients Micronutrients Vitamins Additives Oher components Processing Cooking methods Probiotic effects Effects on microbiome...

MRC | Medical Research Council

Dietary priorities for T2DM/cardiometabolic disease



Food choice: complex influences! Individual & societal



Thank you





(2) Type of replacement nutrient matters

Pooled Analysis of 11 Prospective Cohort Studies



Total of 344,696 individuals with 5,249 CHD events. *p<0.05

(Jakobsen et al, AJCN 2009)

Fish intake

• It is proposed that fish intake is likely to be beneficial for the prevention of type 2 diabetes, based on the benefits for cardiovascular health

Meta analyses of fish and type 2 diabetes

Meta analyses	Wallin,	Wu,	Xun,	Zhou,	Zheng,
	Diabetes Care,	Br J Nutr,	Diabetes Care,	Br J Nutr,	PLOS ONE,
	2012,	2012	2012	2012	2012
	13 studies	13 studies	12 studies	9 studies	11 studies
	21,173 T2D	20,830 T2D	18,711 T2D	18,272 T2D	18,047 T2D
Overall	1.01	1.12	1.00	1.15	1.07
Relative risk	0.99, 1.03	0.94, 1.34	0.85, 1.18	0.98, 1.35	0.91, 1.25
(95% CI)	Per serving/week	Per 100g/day	Highest/lowest	Highest/lowest	Highest/lowest

Fish and T2D: Location matters



Wallin A Diabetes Care, 2012, 35:

Study				(95% CI)
North America/Europe				
Djousse_WHS (2011)			•	— 1·96 (1·58, 2·43
Van woudenbergh (2009)			•	→ 1.95 (1.01, 3.78
Vang (2008)			•	→ 1.80 (0.57, 5.72
Kaushik_NHS2 (2009)		•		1.41 (1.15, 1.73
Kaushik_NHS (2009)		_		1.29 (1.11, 1.49
Kaushik_HPFS (2009)		_		1.22 (1.03, 1.43
Djousse_CHS (2011)				0.74 (0.32, 1.71
Patel (2009)	-			0.13 (0.02, 0.78
Overall (P=70·1%)	<	>		1.38 (1.13, 1.70
Asia				1.00 (0.82, 1.23
Brostow (2011)	•			0.99 (0.75, 1.32
Nanri_JPHCW (2011)				0.96 (0.71 1.30
Villegas_SMHS (2011) -	•			0 30 (0 71, 1 30
Villegas_SWHS (2011) —	•			0.82 (0.69, 0.97
Nanri_JPHCM (2011)	•			0.80 (0.64, 1.00
Overall (/ ² =0%)	\diamond			0.89 (0.81, 0.98
1		I	I	1
0.5	1.0	1.5	2.0	2.5
Per 100 g/d				
	407			



Fish intake and T2D: diet advice

- Findings for association with diabetes are different by geographic location
- Why might this be?
 - Contaminants (e.g. methyl mercury)
 - Cooking methods
 - Confounding factors
- More research is needed
- Not ready for public health recommendations specifically on the benefits or harms of fish intake for T2D
- Meanwhile follow public health recommendations on fish intake for cardiovascular benefit

'To consume 1-2 portions of fish per week, one of which should be oily' COMA report 1994, SACN, 2004

Meat intake and diabetes: diet advice

- Higher meat intake is associated with increased risk of T2D
- Limitations of observational epidemiology are acknowledged
- But, findings cannot be ignored
- 33% of UK adults are high meat consumers (>100 g/d)

Limit intake of red meat to 500g cooked weight a week and avoid processed meat – World Cancer Research Fund (WCRF)



Dietary Assessment



Whose food intake is different between weekdays and weekend days?

Who eats out more than once in a week? who skips breakfast?

Who cooks from scratch at least once in a week?

Who consumed fish in the last 7 days?

Who follows a special diet?

Who takes supplements?

Has anyone ever recorded their dietary intake?

Fruit and vegetable intake and incidence of type 2 diabetes mellitus: systematic review and meta-analysis

Carter P et al, BMJ 2010



Total Fruit/Vegetables





Green leafy vegetables





SYSTEMATIC REVIEW

Fruit and vegetable intake and type 2 diabetes: EPIC-InterAct

prospective study and meta-analysis European Journal of Clinical Nutrition (2012)

ORIGINAL ARTICLE

A Prospective Study of the Association Between Quantity and Variety of Fruit and Vegetable Intake and Incident Type 2 Diabetes

Diabetes Care, 2012, 35:

ANDREW J. COOPER, MPHIL¹ STEPHEN J. SHARP, MSC¹ MARLEEN A.H. LENTJES, MSC² ROBERT N. LUBEN, BSC² KAY-TEE KHAW, FRCP, PHD³ Nicholas J. Wareham, frcp, phd¹ Nita G. Forouhi, ffph, phd¹

Comparing extreme thirds (adjusted analysis, including quantity of intake) **Total F&Veg: RR 0.61 (0.48 – 0.78) Fruit: RR 0.70 (0.53 – 0.91) Veg: RR 0.77 (0.61 – 0.98)**

Dairy intake & T2D: using 7-day food diary

Hazard Ratio [95% CI] for risk of T2D associated with energy-adjusted dairy product intake, Tertile 3 versus Tertile 1, multivariable model

N=4,127



O'Connor et al Diabetologia 2014