Energy Density and Eating Rate Moderate Energy Intake from UPF's

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https://restructureproject.org/

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NATIONAL ACADEMIES Sciences Engineering Medicine

Declarations: Funding Sources and Committee Memberships

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Committee: Member of the Non-nutritive Sweeteners Committee for the Institute for the Advancement of Food and Nutritional Science (IAFNS), advisor to IAFNS on Food Processing Classification, Member of the Advisory Group to UKRI Public Consultation on UPF. Scientific Advisory Board for ILSI Europe (2026-2029), Global Scientific Advisory Committee for Lesaffre (2024-present), Scientific Advisory Board Institute for Food and Health, University College Dublin (IRL). Former member of the Kerry Health and Nutrition Institute KHNI, (2017-22).

Editor: European Journal of Nutrition (Section Editor: Nutrition Behaviour), Journal Texture Studies, Nutrition Bulletin, Journal Future Food.

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The Context; Why focus on Energy Density and Eating Rate?

‘UPF consumption in observational studies is strongly associated with increased risk of obesity and obesity-related metabolic complications. Only a handful of RCT’s have looked at UPF and energy intake’

Do UPF’s drive passive “overeating” ?

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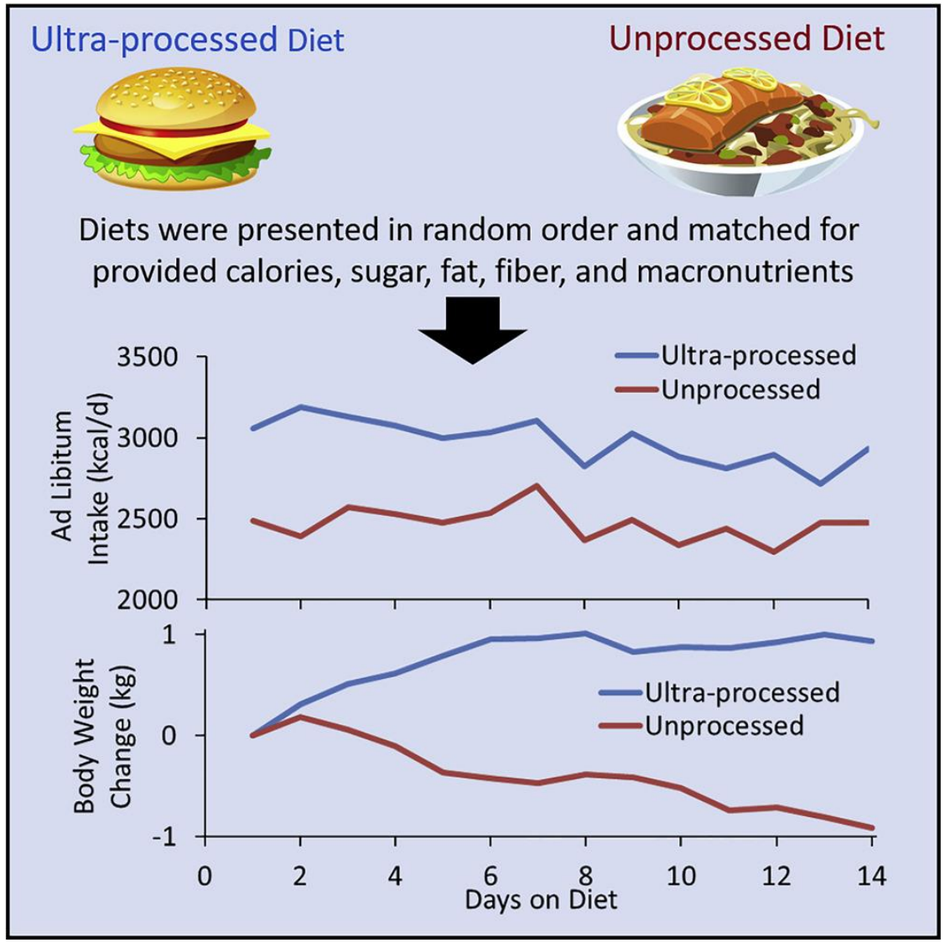
UPF RCT's: Effects on Energy Intake and/or body weight

Multiple Day (UPF vs. Minimal Processed)
Hall (2019) – Cell Metabolism
Hamano (2024) – Diabetes, Obesity & Metabolism
Dicken (2025) – Nature Medicine
Discepoli (2025) - Journal of Clin Periodontology
Preston (2025) – Cell Metabolism
Santos de Oliveira (2025) – Food & Function

Single days or single meals (UPF vs. Minimal Processed)
Teo (2022) - American Journal of Clinical Nutrition
Lasschuijt (2023) – European Journal of Nutrition
Larcom (2025) - Appetite



Hall *et al* (2019) ***Cell Metabolism***

Is Ultra-processing to blame or differences in energy density?

RCTs and Energy Density

Hall (2019) – ***Cell Metabolism*** [94% ↑ UPF arm]
Hamano (2024) – ***Diabetes, Obesity & Metabolism*** [55% ↑ UPF]
Dicken (2025) – ***Nature Medicine*** [24% ↑ UPF arm]

- Trial results could easily be the reversed if energy density was made higher on the minimally processed diet.
- Evidence suggests reducing energy density can also significantly reduce daily energy intakes.

With inputs from Prof. Faidon Magkos (KU), Prof. Eric Robinson (Liverpool).

Differences in total* or solid food energy density (kcal/g)

		Comparator	UPF
Preston (2025)	Total*	1.8	1.8
Hamano (2024)	Total	1.1	1.7
	Solid	1.1	2.0
Hall (2019)	Total	1.03	1.02
	Solid	1.06	1.96
Dicken (2025)	Total*	**1.37**	**1.7**

*foods and beverages (solid ED not reported separately)

Robinson *et al. Int J Behav Nutr Phys Act* (2022) 19:48
https://doi.org/10.1186/s12966-022-01287-z

International Journal of Behavioral Nutrition and Physical Activity

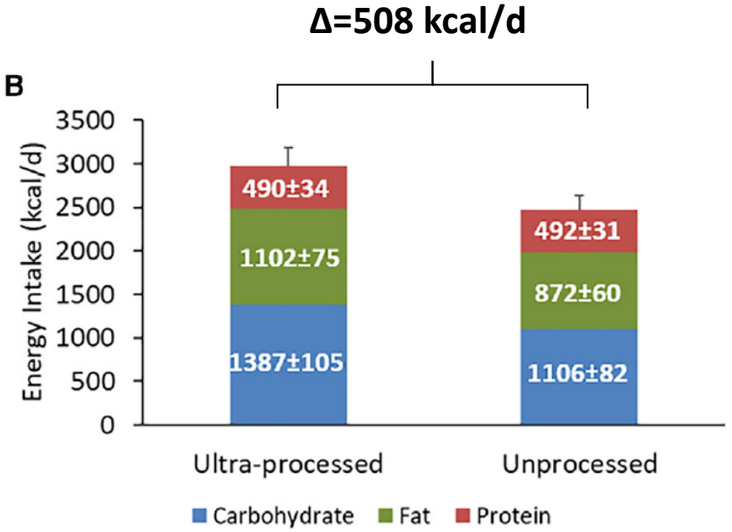
RESEARCH Open Access

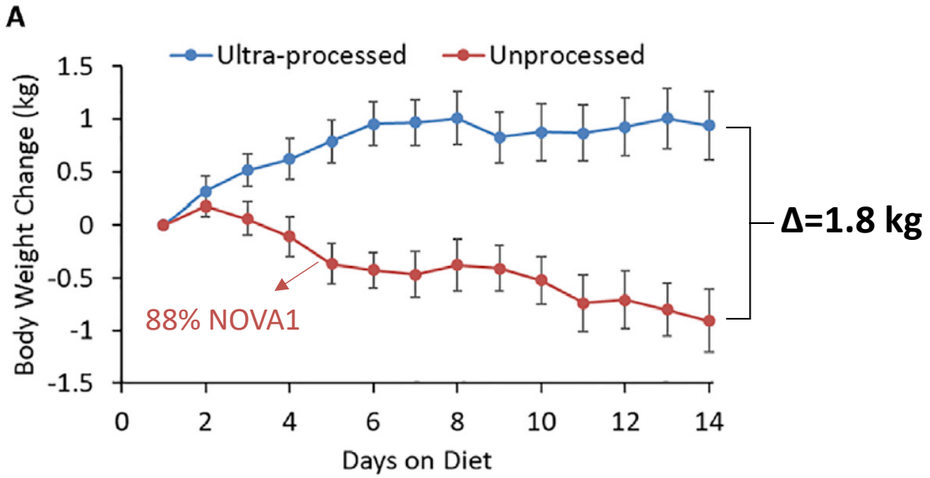
Calorie reformulation: a systematic review and meta-analysis examining the effect of manipulating food energy density on daily energy intake

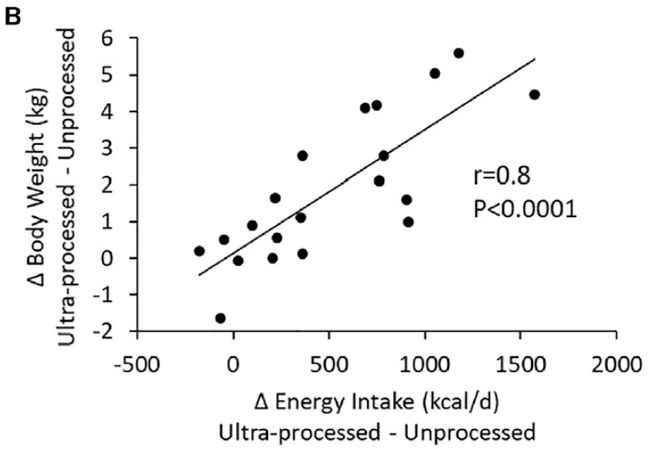
Eric Robinson*, Mercedes Khuttan, India McFarland-Lesser, Zina Patel and Andrew Jones

Do UPF's drive passive "overeating" ?

- 20 M+F without obesity, fed ***ad libitum*** for 2 weeks with UPF or MPF, in a randomized crossover inpatient design (no washout).
- The UPF diet had **~2-fold higher solid food energy density** (matched total), and **higher proportions of added/total sugars, insoluble/total fiber, and saturated/total fat**.



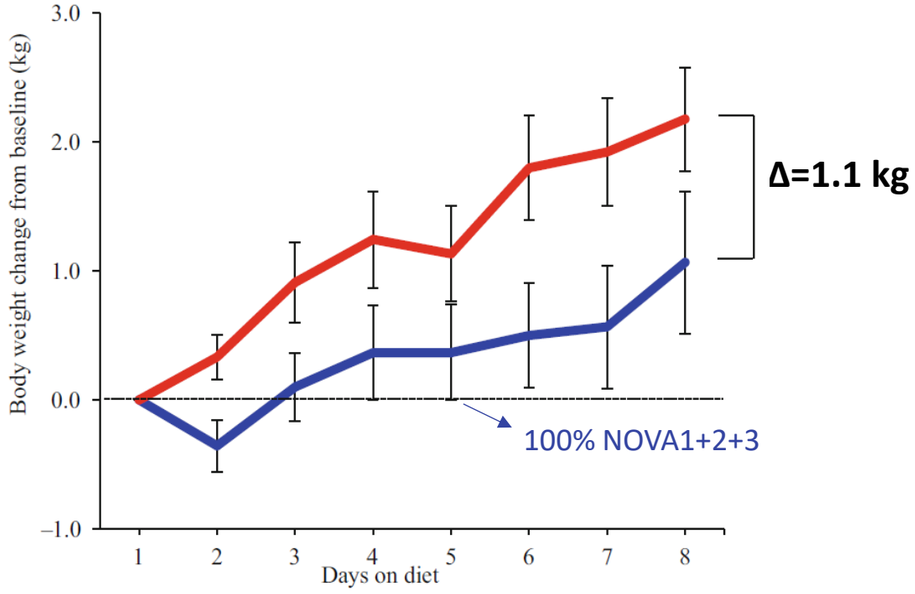


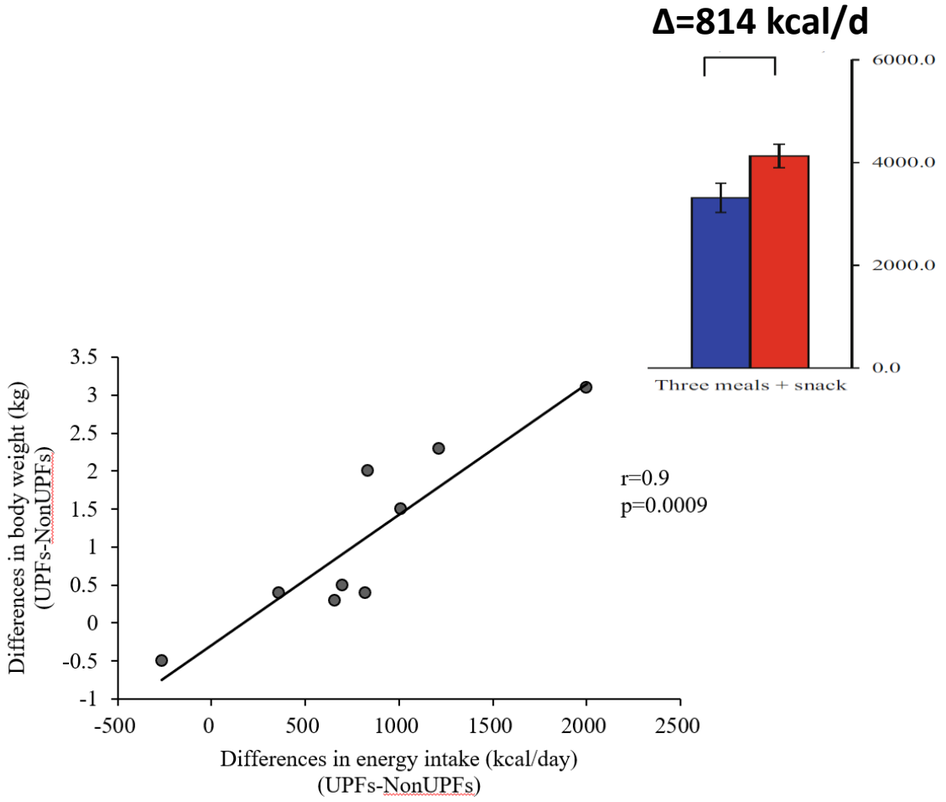


Hall *et al* (2019) ***Cell Metabolism***

Do UPF's drive passive "overeating" ?

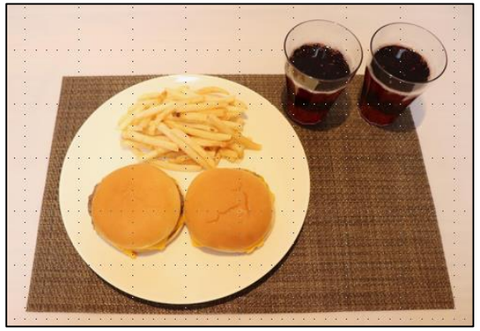
- 9 M with obesity (Asian), fed **ad libitum** for 1 week with UPF or Non-UPF, in a randomized crossover design with 2 weeks washout (inpatient).
- The UPF diet had **~2-fold higher total and solid food energy density, and about half the amount of fiber and 50% more SFA**.





Minimal processed diet

UPF diet

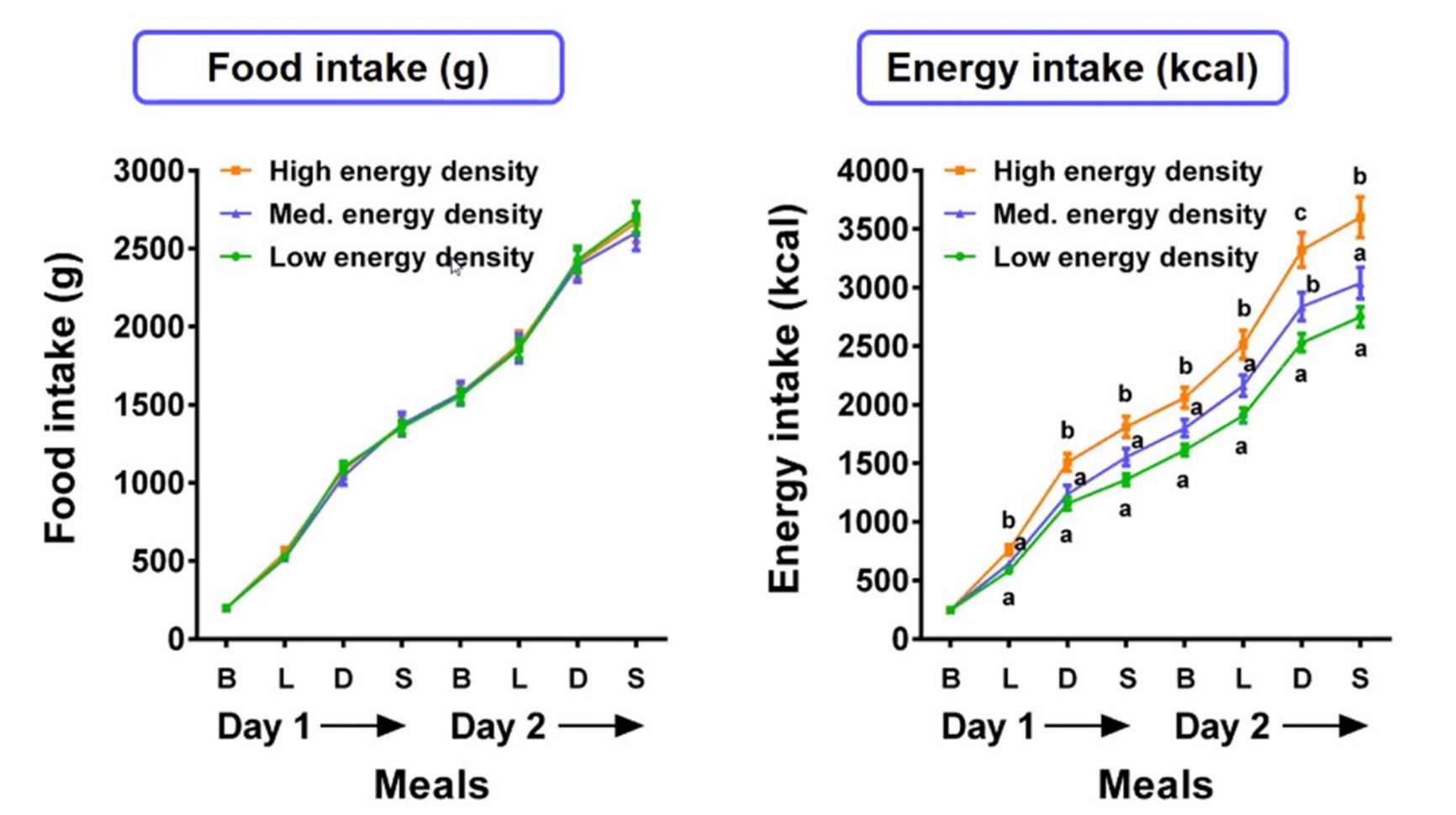


Hamano (2024) ***Diabetes Obes Metab*** 26(11)5431

The effect of Energy Density on Energy Intake (acute)

<u>Consistent evidence</u> from many controlled studies that meal energy density drives intake

(in adults, children, at breakfast, lunch, dinner, snacks, across different macronutrients...etc)



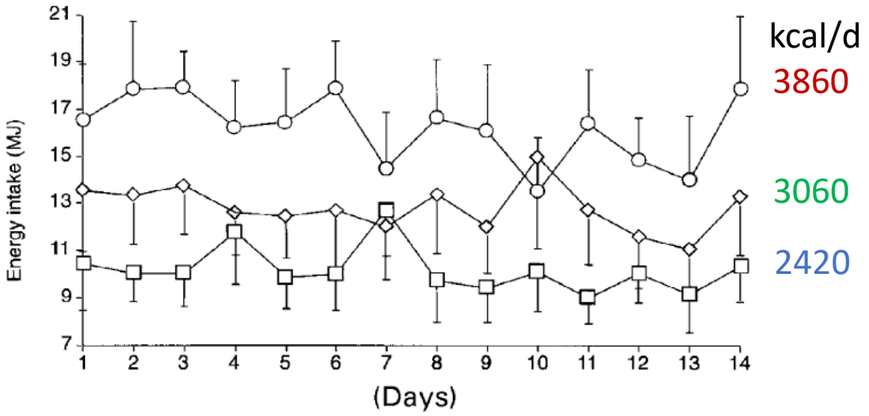
Prof. Barbara Rolls
Penn State

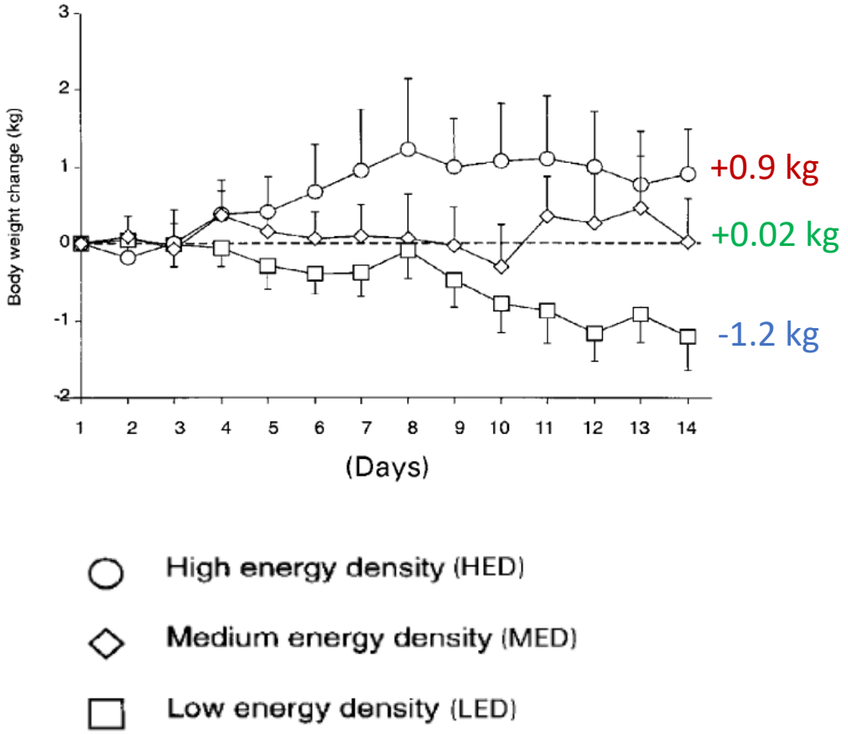
Bell et al (1998) ***American Journal of Clinical Nutrition***

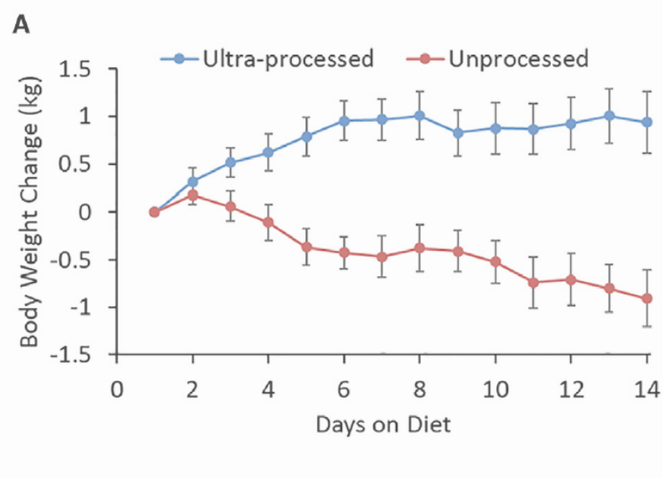
Energy density as a determinant of Energy intake and Weight (2wks)

1.06 kcal/g **1.96 kcal/g**

- 6 lean M, fed **ad libitum** for 14 days with low (**0.85 kcal/g**), medium (1.3 kcal/g), or high (**1.75 kcal/g**) energy density (**covertly manipulated**), in a randomized crossover design with a 4-day washout (pseudo-inpatient).







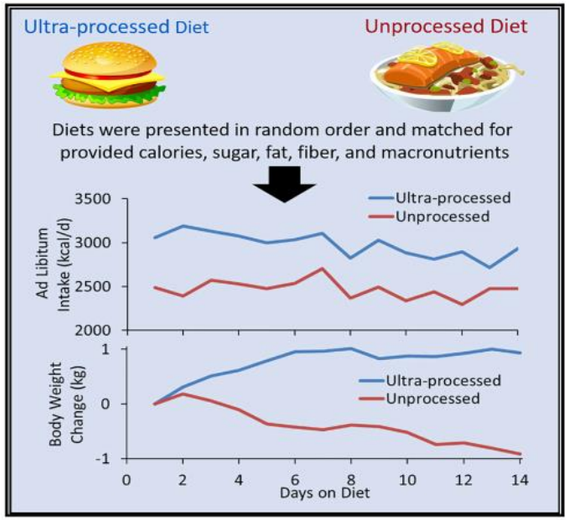
Stubbs *et al* (1998) ***Int J Obes Relat Metab Disord***

Hall *et al* (2019) ***Cell Metabolism***

Do UPF's drive passive "overeating" ? A role for Eating Rate...

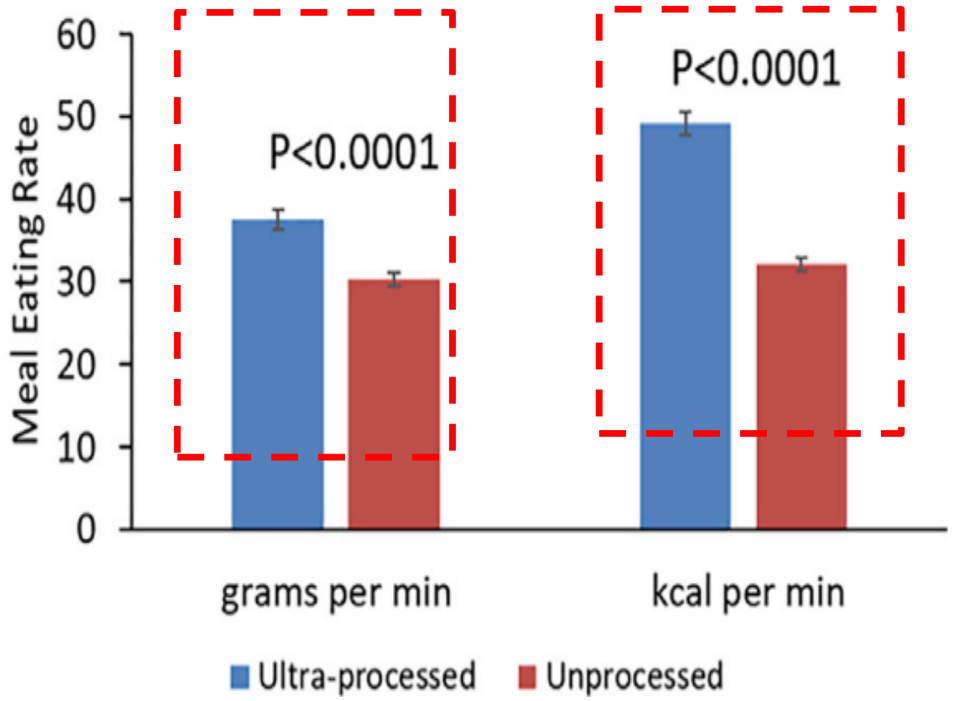
Cell Metabolism

Ultra-Processed Diets Cause Excess Calorie Intake and Weight Gain: An Inpatient Randomized Controlled Trial of *Ad Libitum* Food Intake

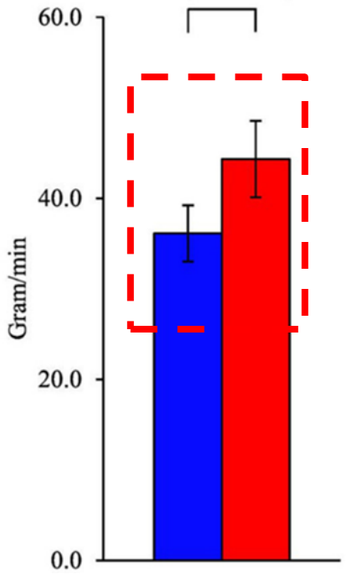


Δ7.7 g / min higher ER for UPF

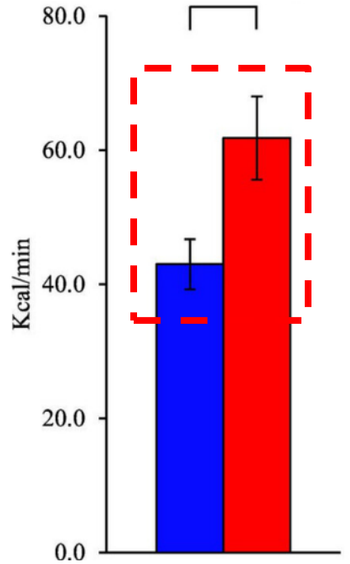
50% higher energy intake rate (Δ**17** kcal/min)



Δ=8.2 g/min



50% higher energy intake rate (Δ19 kcals/min)

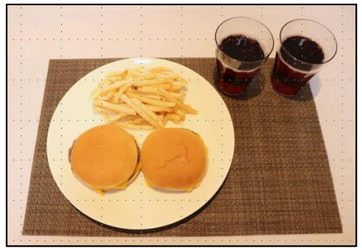


RCTs and Eating Rate

- ED and ER always higher on the UPF diet arm.
- Eating rate; an effect moderator for energy density

Hall et al (2019) ***Cell Metabolism***

Ultra-processed diet **Minimal processed diet**

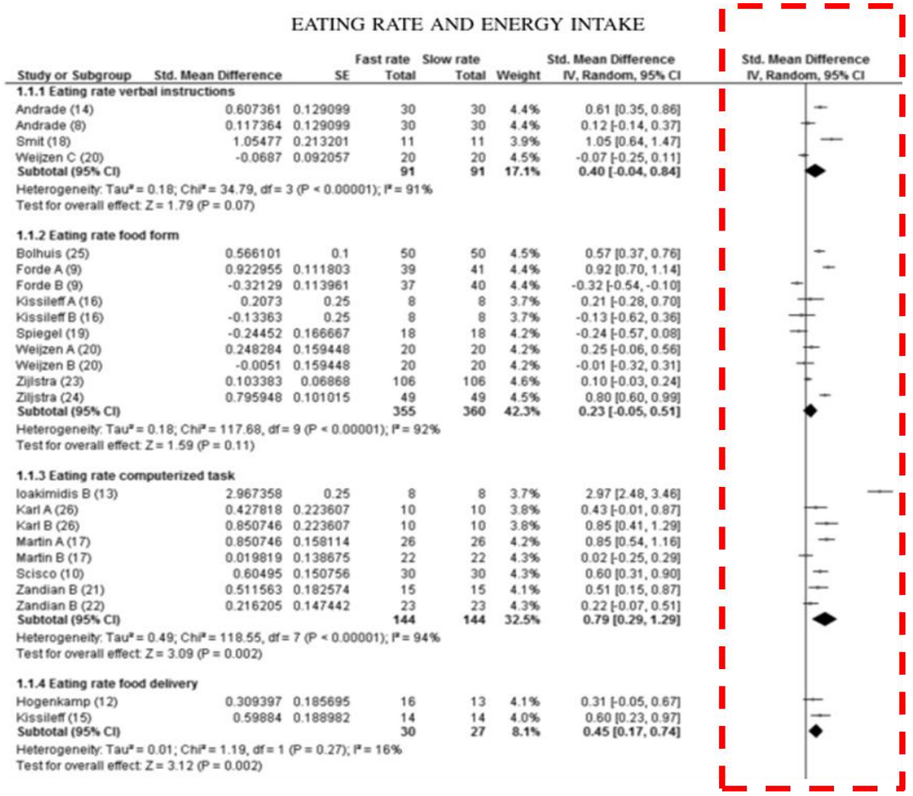


Hamano (2024) ***Diabetes Obes Metab*** 26(11)5431

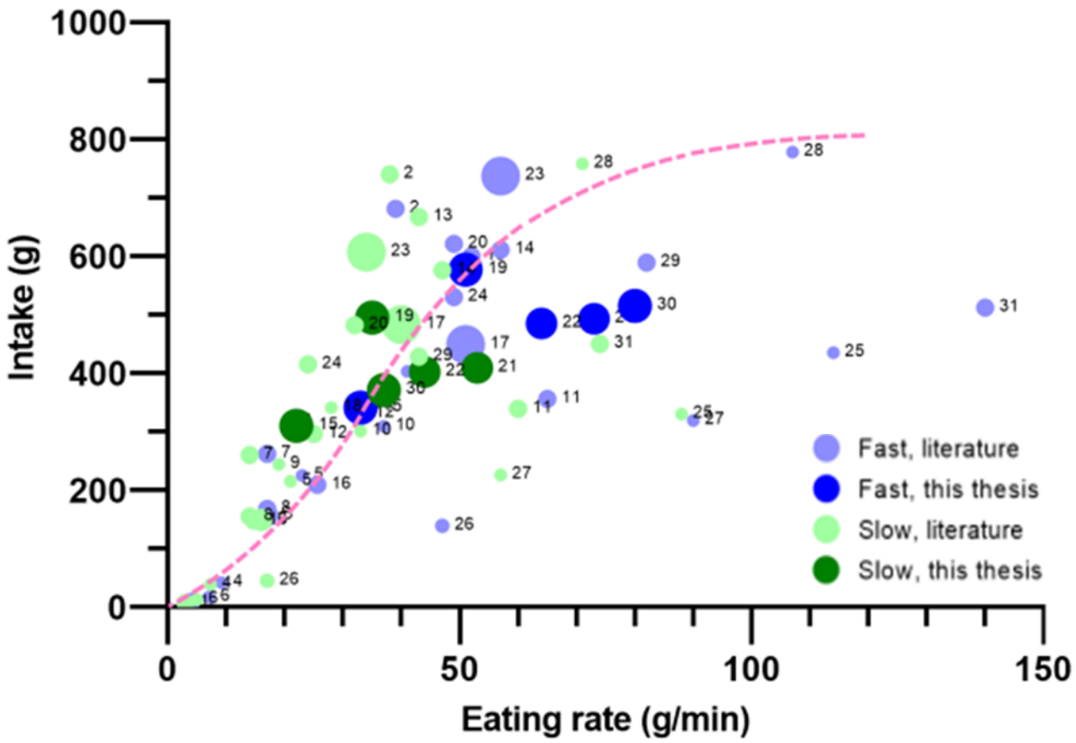
The effect of Eating Rate on Food and Energy Intake

<u>Consistent evidence</u> from acute feeding studies that meal texture moderates eating rate and energy intake
(in adults, children, across meal occasions, prospective birth cohorts, controlled feeding trials, population studies, across age, gender…)

Meta-Analysis Faster Eating Rate ↑Ad Lib Energy Intake



Robinson *et al* (2014) ***American Journal of Clinical Nutrition***



Eating rate (g/min) versus food intake (g) of 24 studies and 182 foods/meals. Data

Forde *et al* , 'Food texture influence on eating rate and intake' (unpublished data)

What is the combined effect of Eating Rate and Energy Density on intake?

- Cross-over *ad libitum* controlled feeding trial
- **N = 69** participants, appetite standardised before each test meal
- 2 (ED) x 2 (ER) test meals + 1 control lunch meal (medium ED and ER) (~350 meals)

Slower Eating Rate

Control

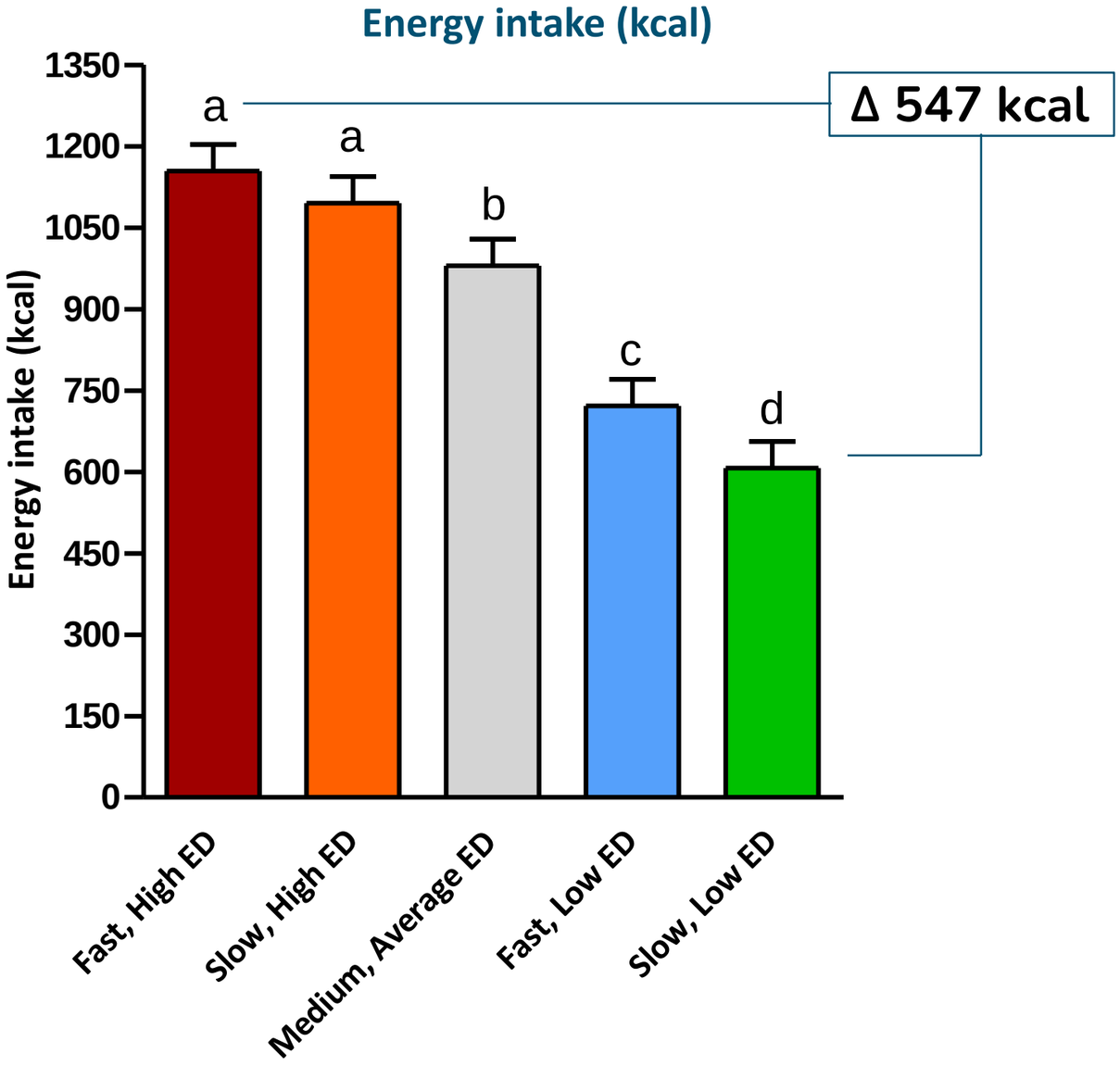
Medium Eating rate

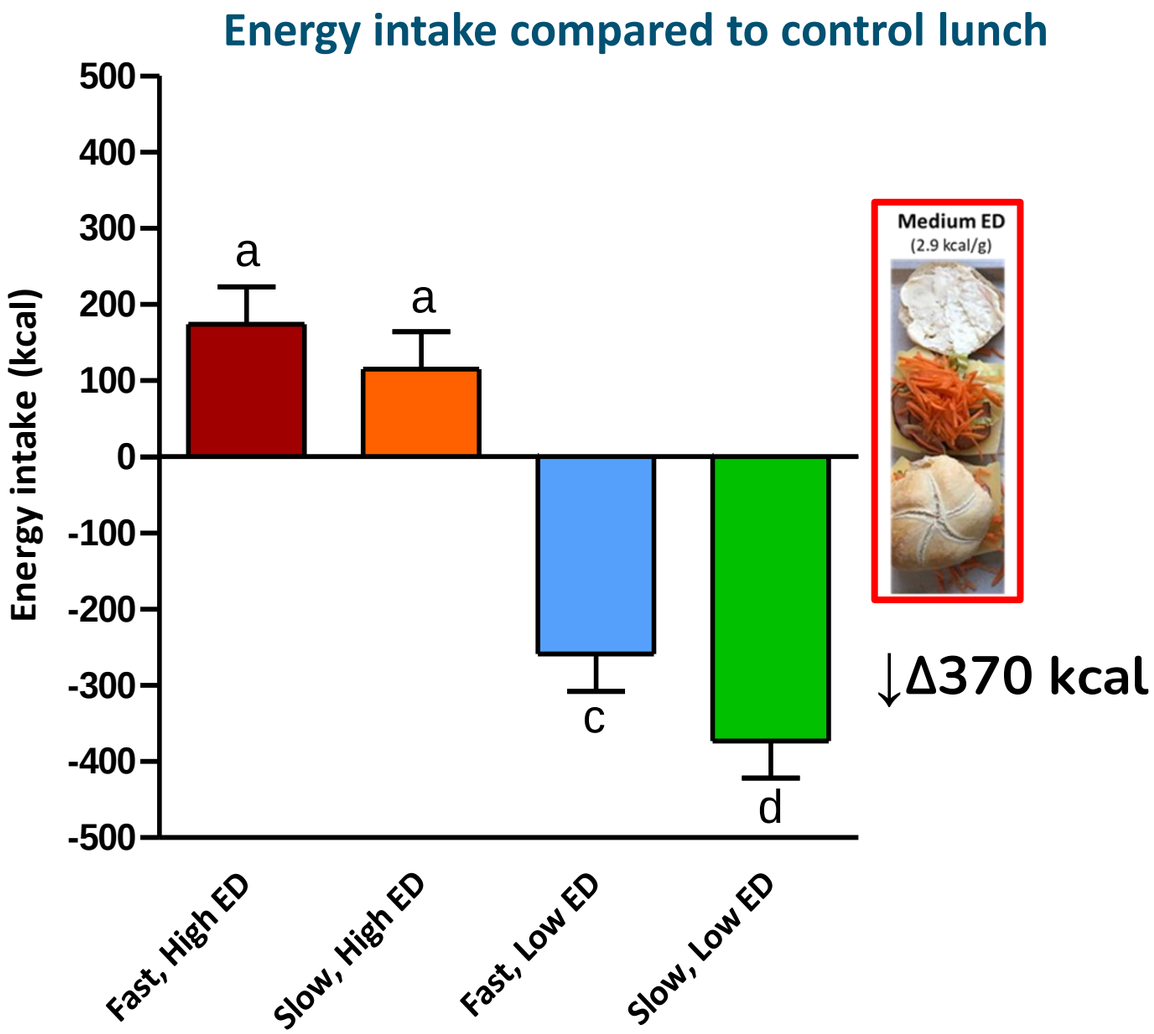
Faster Eating Rate

All Meals were UPF (Nova 4) and all were Matched for liking

Lasschuijt *et al* (2025) ***Journal of Nutrition***

What is the combined effect of Eating Rate and Energy Density on intake?





Lasschuijt *et al* (2025) ***Journal of Nutrition***

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The Restructure Project

Understanding the impact of texture-based differences in eating rate on energy intake from Ultra-Processed Diets

Prof. C. Forde (PI)

Lise Heuven, PhD

Marieke van Bruinessen
(PhD Student)

Zhen Liu
(PhD Student))

A-Prof. M. Lasschuijt

Prof. M. Stieger

A-Prof. J. Rubert

TKI-Agri-Food (NL) LWV22150;'RESTRUCTURE'

https://restructureproject.org/

Clinical Trials: NCT06113146

Restructure RCT – study outcomes

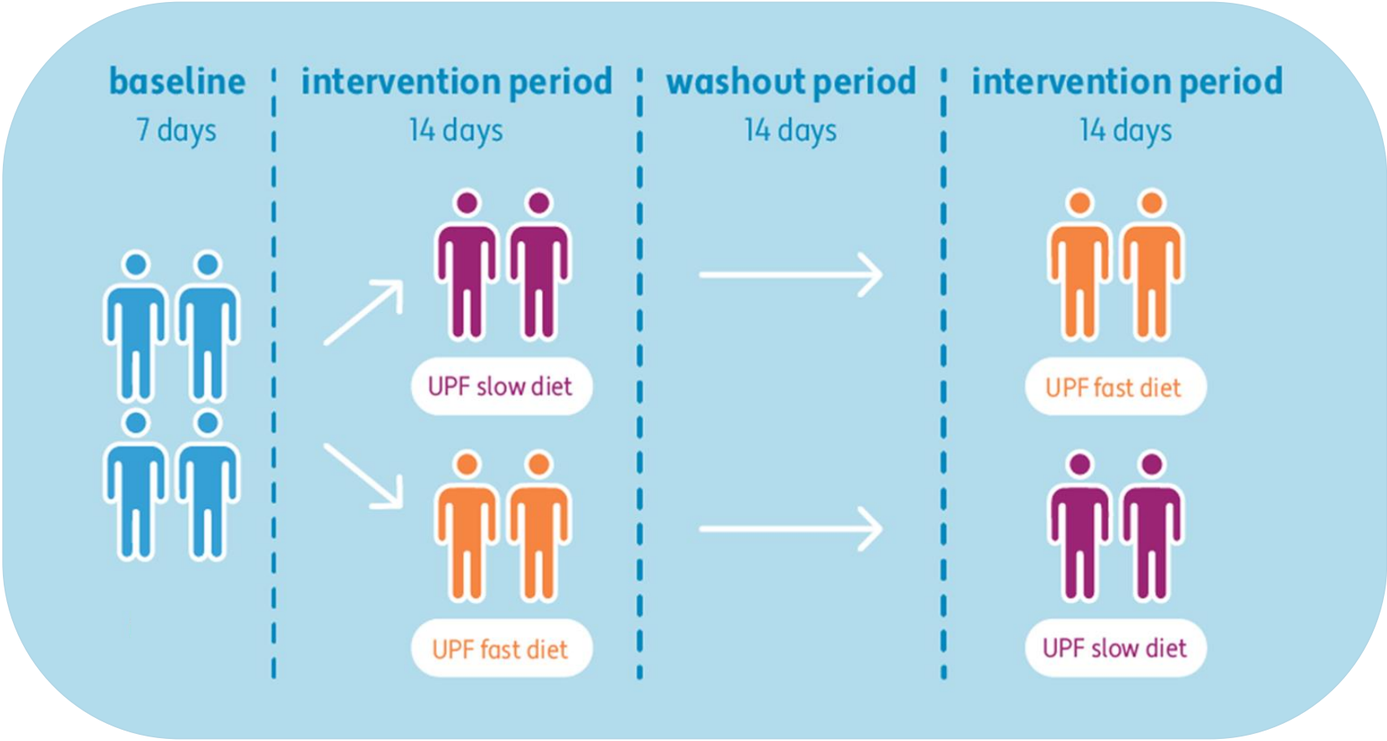
https://restructureproject.org/

Primary Outcome

To determine the effect of Meal Eating Rate (UPF slow ER vs UPF fast ER) on *ad libitum* daily energy intake from UPF diets (kcal/day) across a 2-week period.

Secondary Outcomes

Changes in Body composition and metabolic markers of health (i.e., satiety, glucose, gut-microbiome)



>5,000 kg of food served
3,444 meals / **1,142** menu days

Clinical Trials: NCT06113146

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Lasschuijt *et al* (2025) ***Nutrition Bulletin*** (Protocol)
Forde *et al* (2025) ***AJCN*** (RCT outcomes)

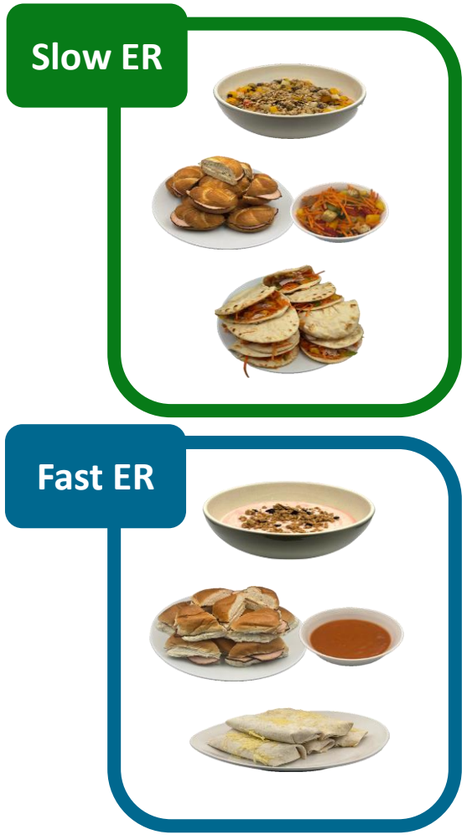
UPF –Fast vs. Slow Study Diets

Key Difference

Meal textures selected to slow down or increase eating rate

Matched on:

- Ultra-Processed Foods (~ 95 EN% Nova 4)
- Portion size (g; kcal) & Meal volume
- Non-beverage Energy density (kcal/g)
- Variety (i.e., number of components)
- Matched for Palatability & Familiarity
- Diets consumed to fullness on both arms

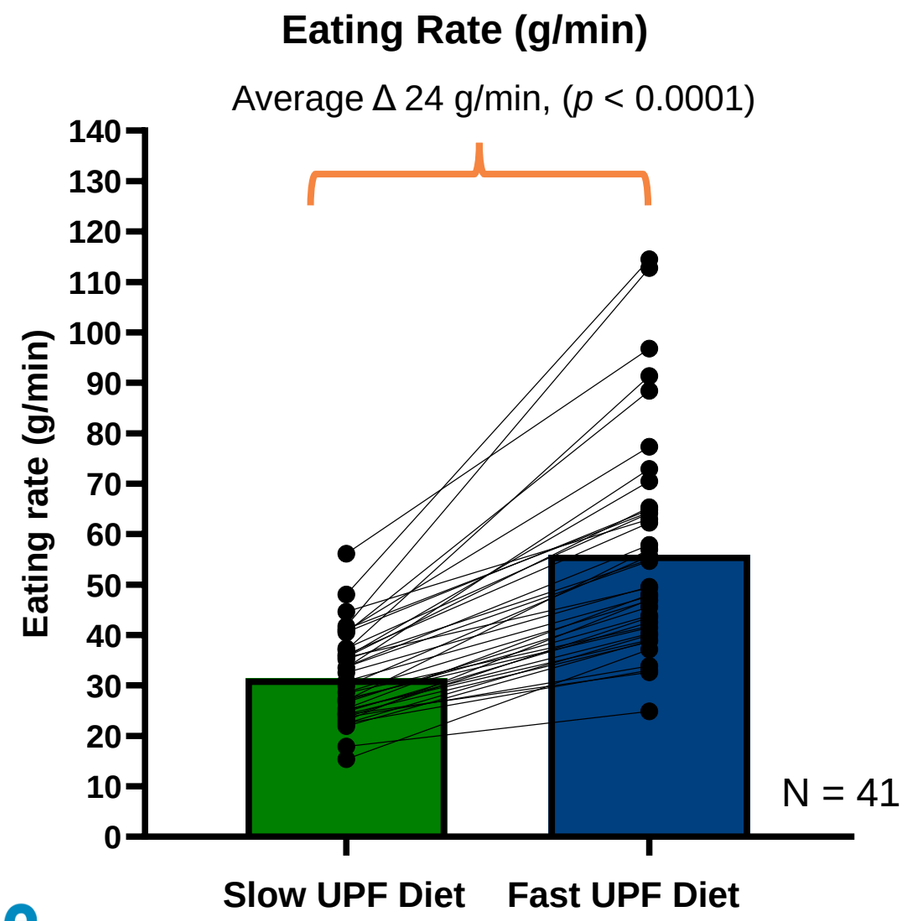


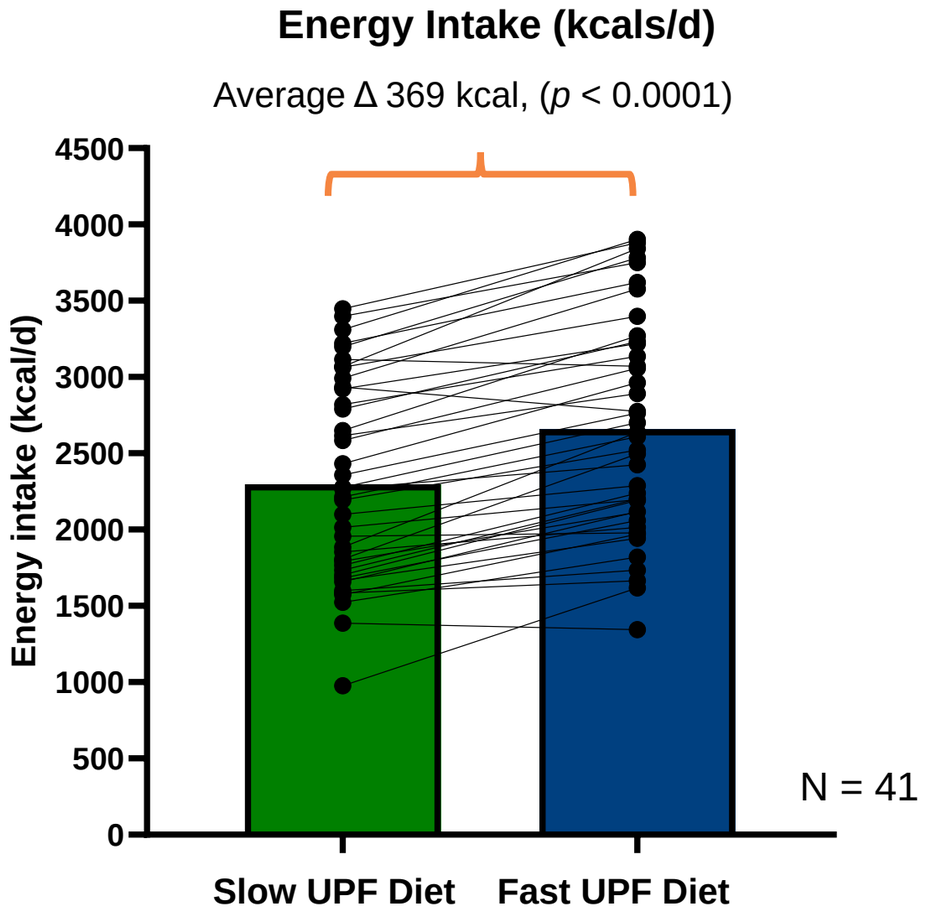
Daily Menu Averages	UPF Slow-ER	UPF Fast-ER
Amount (g)	3821	3823
Energy (kcal)	5831	5835
Non-beverage Energy density (kcal/g)	1.53	1.53
Ultra-processed foods (EN%)	97	94

Lasschuijt *et al* (2025) ***Nutrition Bulletin*** (Protocol)
Forde *et al* (2025 – in Press) ***AJCN*** (RCT outcome)

Is energy intake from UPF moderated by Meal Texture ?

Consistent effect of Meal Texture on Eating Rate and Energy Intake Across All Participants
A Slower Eating rate reduced daily energy intake by an average of 369 kcal/d (CI: 221, 517)





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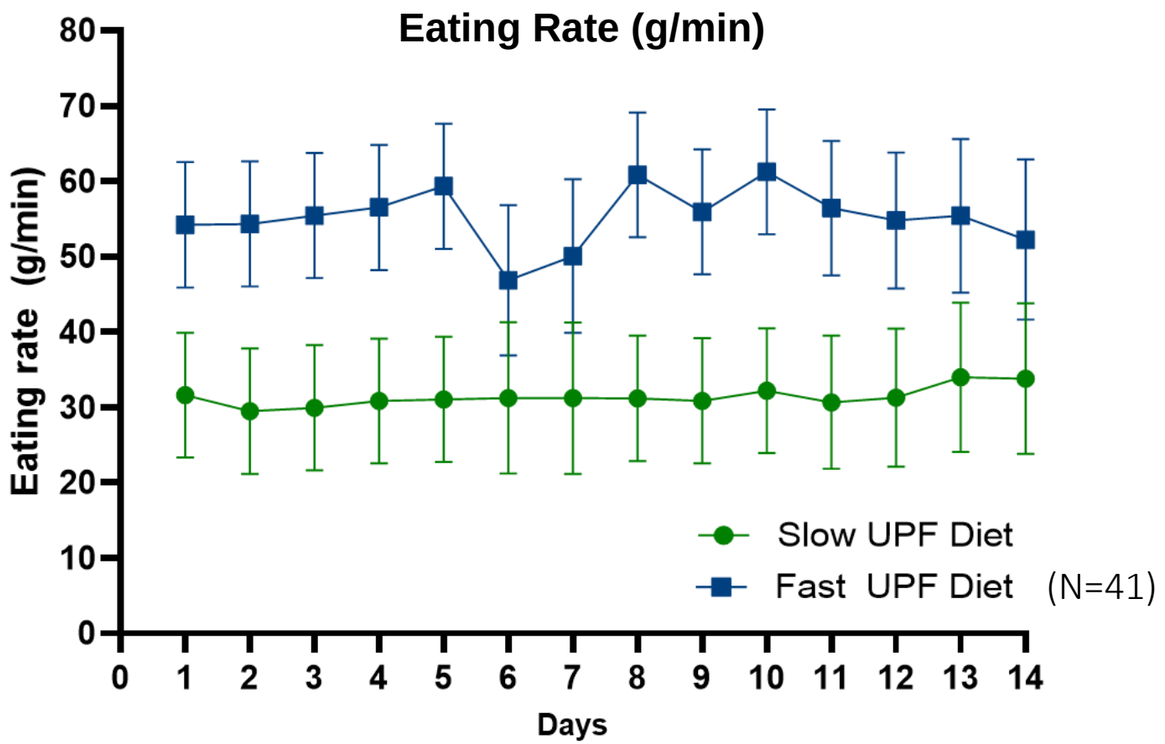
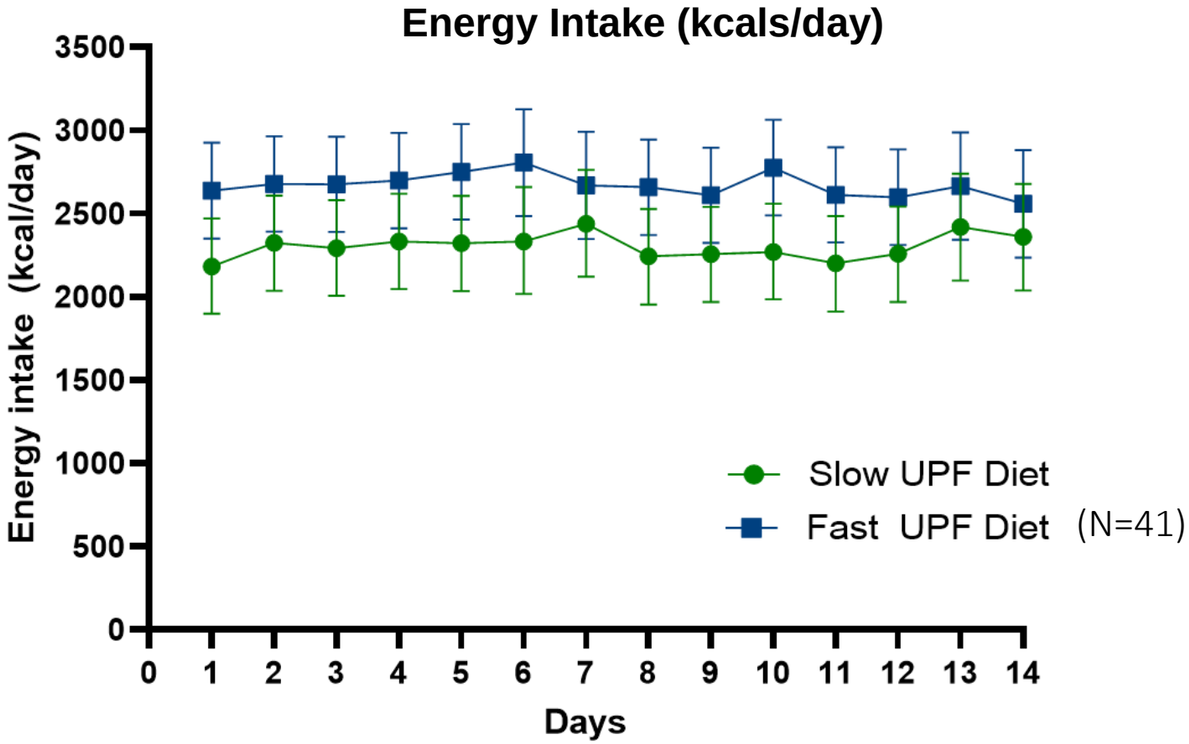
Forde et al. (2025) ***AJCN***

Is the effect of Meal Texture on Energy intake Sustained?

Sustained effect of meal texture on both eating rate and energy intake <u>over 14-days</u> of the diet intervention





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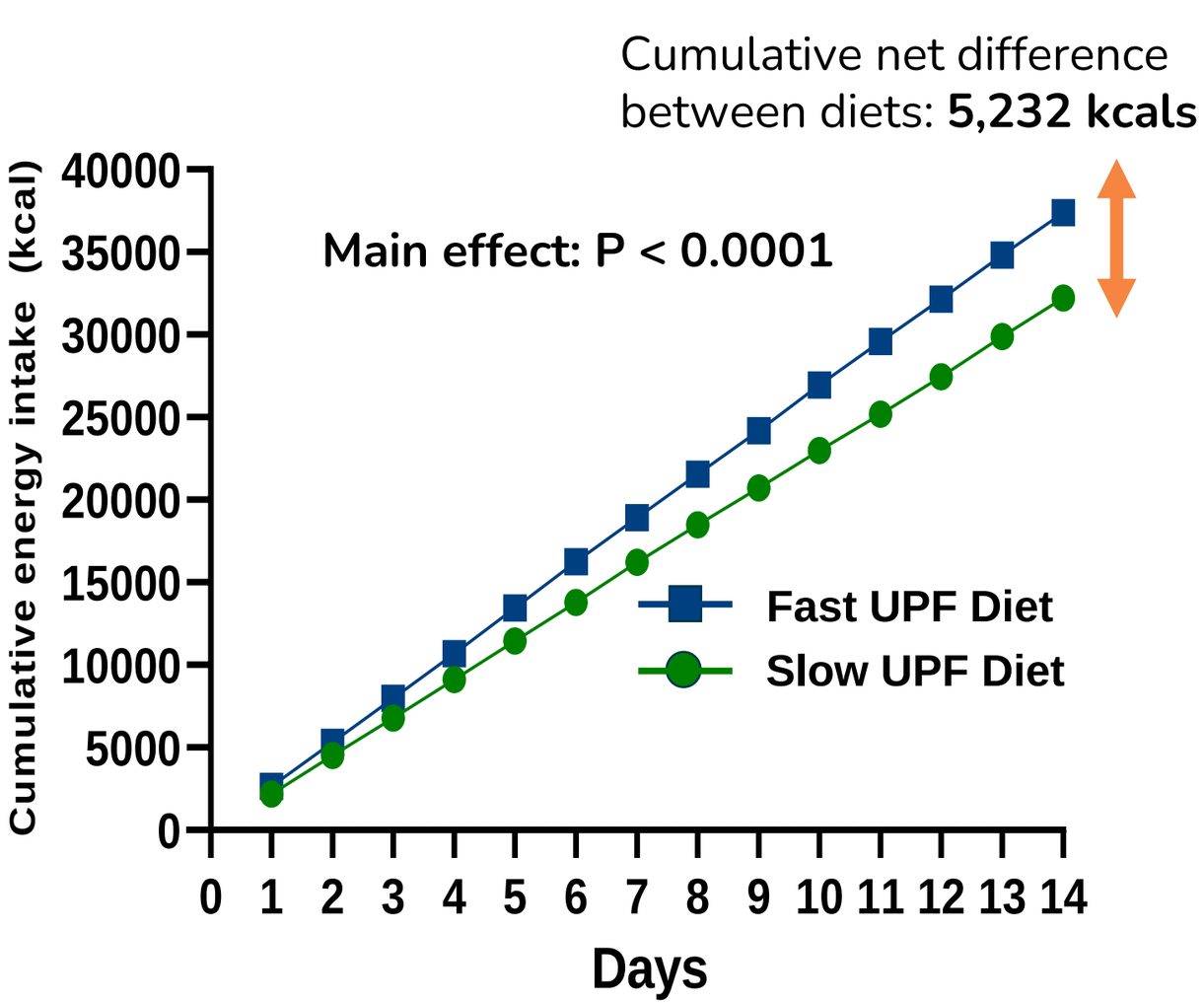
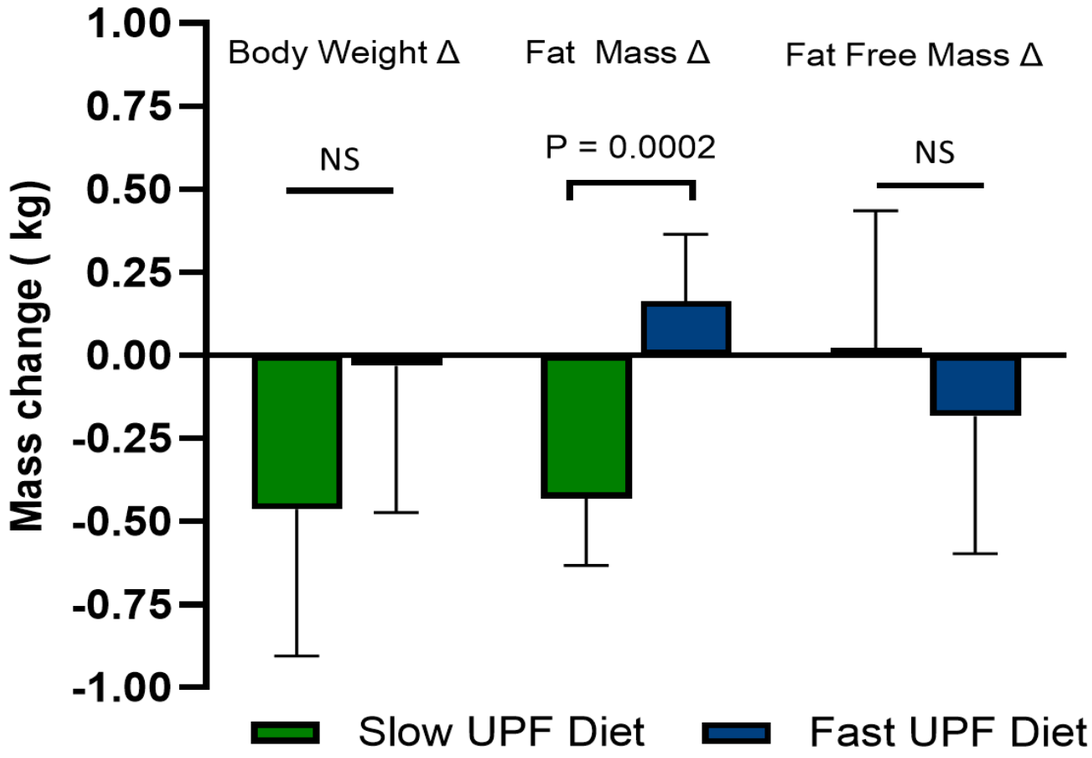
Forde et al. (2025) ***AJCN***

Differences in Cumulative Energy Intake and Fat Mass Between Diets



No sig. differences in body Weight
Slower Eating led to reduced fat mass
(Δ 0.43 kg *p* = 0.0002) between diets



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Forde et al. (2025) ***AJCN***

Conclusions

Energy Density and Eating Rate

Energy density and Eating rate have an independent and combined effect on energy intake.

Implications for Public Health?

Exchanging UPF's for 'unprocessed foods' may be a 'simple' public health message, but available evidence suggests traditional nutritional quality rather than food processing should remain the cornerstone of dietary guidance.

Implications for Food Producers?

Knowing which sensory and nutritional attribute(s) facilitate overeating can enable food structures/formulations to attenuate these effects (i.e. playing on a foods texture, diluting energy density or increasing protein and fiber).

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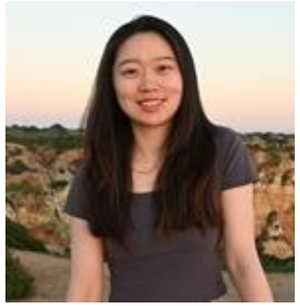
https://restructureproject.org/

reStructure

Special Thanks to

Marieke van Bruinessen
(PhD student)

Lise Heuven, PhD



Zhen Li
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A-Prof. M. Lasschuijt

Karleen Pietersma
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Paris Intzesiloglou
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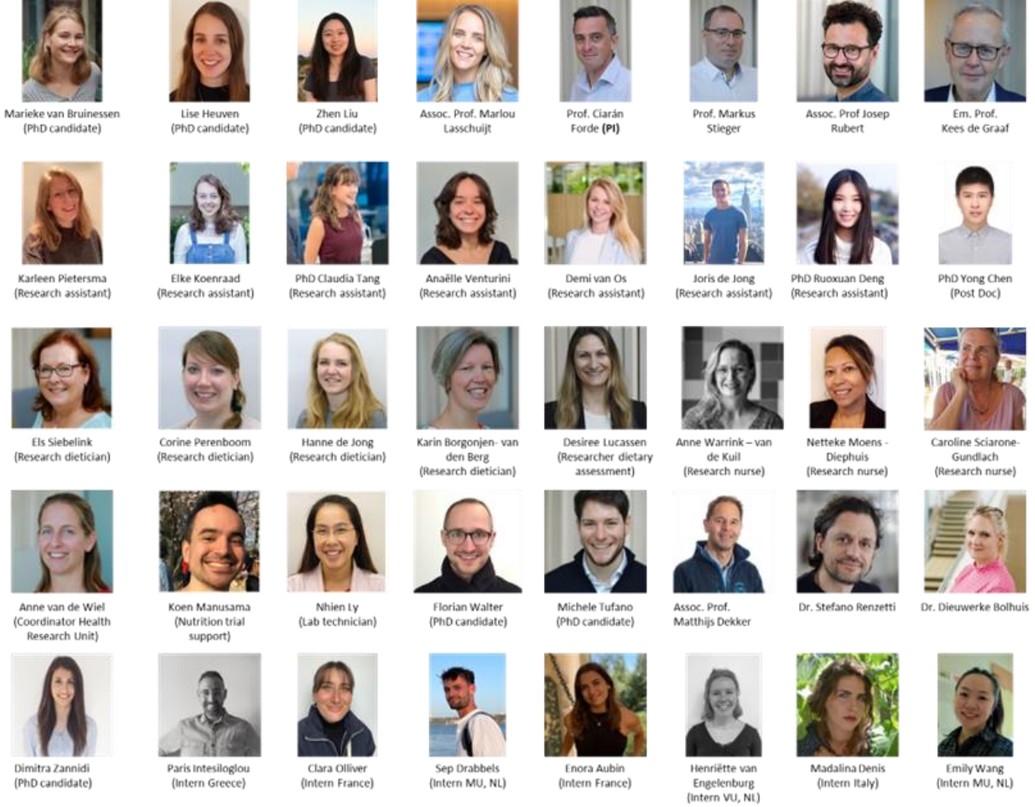

Thank You

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