British Journal of Nutrition

cambridge.org/bjn

Research Article

Cite this article: Price EJ, Kissock KR, Barrett EM, Batterham MJ, and Beck EJ (2025). Whole-grain modified Nova ultra-processed food definitions: a cross-sectional analysis of the impact on cardiometabolic risk measures when excluding high whole-grain foods from the ultra-processed food category in Australia. *British Journal of Nutrition*, page 1 of 11. doi: 10.1017/S0007114524002952

Received: 4 June 2024
Revised: 20 October 2024
Accepted: 7 November 2024

Keywords:
NNPAS; Whole grain; Nova; Ultra-processed food; Cardiometabolic risk

Abbreviations:
AUSNUT, Australian Food, Supplement and Nutrient Database; NNPAS, National Nutrition and Physical Activity Survey; UPF, ultra-processed food; WHR, weight-to-height ratio

Corresponding author:
Eleanor J. Beck;
Email: e.beck@unsw.edu.au

Whole-grain modified Nova ultra-processed food definitions: a cross-sectional analysis of the impact on cardiometabolic risk measures when excluding high whole-grain foods from the ultra-processed food category in Australia

Elissa J. Price[1], Katrina R. Kissock[1,2], Eden M. Barrett[1,2], Marijka J. Batterham[3] and Eleanor J. Beck[1,4]

[1]School of Health Sciences, Faculty of Medicine and Health, University of New South Wales, Sydney, NSW, Australia; [2]The George Institute for Global Health, Faculty of Medicine and Health, University of New South Wales, Sydney, NSW, Australia; [3]National Institute for Applied Statistics Research Australia and Statistical Consulting Centre, School of Mathematics and Applied Statistics, Faculty of Engineering and Information Sciences, University of Wollongong, Wollongong, NSW, Australia and [4]School of Medical, Indigenous, and Health Sciences, Faculty of Science, Medicine, and Health, University of Wollongong, Wollongong, NSW, Australia

Abstract

Ultra-processed foods (UPF), defined using the Nova classification system, are associated with increased chronic disease risk. More recently, evidence suggests the UPF subgroup of whole-grain breads and cereals is in fact linked with reduced chronic disease risk. This study aimed to explore associations of cardiometabolic risk measures with Nova UPF intake *v.* when foods with ≥ 25 or ≥ 50 % whole grains are excluded from the definition. We considered dietary data from the Australian National Nutrition and Physical Activity Survey 2011–2012. Impacts on associations of UPF intake (quintiles) and cardiometabolic risk measures were analysed using regression models. The median proportion of UPF intake from high whole-grain foods was zero for all quintiles. Participants in the highest Nova UPF intake quintile had significantly higher weight (78·1 kg (0·6)), BMI (27·2 kg/m^2 (0·2)), waist circumference (92·7 cm (0·5)) and weight-to-height ratio (0·55 (0·003)) compared with the lowest quintile ($P < 0·05$). Associations were the same when foods with ≥ 25 and ≥ 50 % whole grains were excluded. Adjusted R-squared values remained similar across all approaches for all outcomes. In Australia, high whole-grain foods considered UPF may not significantly contribute to deleterious cardiometabolic risk associations. Until conclusive evidence on Nova UPF is available, prioritisation should be given to the nutrient density of high whole-grain foods and their potential contribution to improving whole-grain intakes and healthful dietary patterns in Australia.

Non-communicable chronic diseases contributed to 89 % of Australian deaths in 2021 and approximately 66 % of the total fatal and non-fatal burden of disease in 2023[1]. A poor diet, namely, one high in energy, saturated fat, added sugar and Na and low in vegetables, fruits, whole grains and high-fibre cereals, was estimated to account for 7·3 % of the total disease burden in 2015[2]. Diet plays a key role as a preventative risk factor for non-communicable chronic disease prevalence.

The Australian Dietary Guidelines, developed by the National Health and Medical Research Council, aim to provide evidence-based nutrition and dietary recommendations[3]. To improve nutrient intakes and combat disease burden, the guidelines recommend to 'only sometimes or in small amounts' consume discretionary foods, which are foods defined as high in energy (relative to nutrients), saturated fats and/or added sugars and added salt and are low in essential nutrients such as fibre[3].

More recently, foods have been categorised based on the nature, purpose and level of processing they undergo as described by the Nova food classification system[4]. Ultra-processed foods (UPF) are defined as formulations of ingredients, specifically non-culinary ingredients and mostly being of exclusive industrial use, typically requiring the use of industrial techniques and processes for creation[4]. Emerging evidence links UPF intake with poor health outcomes including higher risk of obesity, type 2 diabetes and hypertension[5,6]; however, little evidence exists about the direct implication of processing on their healthfulness separate from that of nutritional quality. Although Nova categorises foods based on the degree of processing, a majority of UPF are of similar nutritional quality to that of discretionary foods, and likewise, limited intake is recommended[7]. However, there are exceptions. According to previous research exploring the classification of foods across both systems, a significant 40·1 % of foods in

the Australian Food, Supplement and Nutrient Database (AUSNUT) 2011–2013 are classified as both ultra-processed and as belonging to core foods groups (foods high in essential nutrients and low in energy) in the Australian Dietary Guidelines[7].

Whole-grain breads and cereals make up a large proportion of these anomalously categorised foods[8]. The Australian Dietary Guidelines recommend to 'enjoy a wide variety of nutritious foods from these five food groups every day: grain (cereal) foods, mostly whole grain and/or high cereal fibre varieties, such as breads, cereals, rice, pasta, noodles, polenta, couscous, oats, quinoa and barley'[3]. Further, these foods are primary contributors to meeting the daily whole-grain intake target of 48 g/d in Australia, which 73 % of Australians currently do not meet[9]. Both recommendations were developed on the basis of long-standing evidence linking whole-grain consumption with reduced risk of various chronic diseases[10]. Therefore, it is unsurprising that emerging research shows that intake of these whole-grain containing UPF does not contribute to deleterious health effects typically linked with UPF intake[11,12] but rather is health protective. In addition, in many countries, these foods are part of mandatory fortification. The addition of thiamine, iodine and folic acid in bread-making flour is linked with prevention of conditions associated with deficiencies of such nutrients[13], such as neural tube defects with folic acid[14], further highlighting the potential healthfulness of these foods.

Our prior published work found that excluding higher whole-grain containing foods from the UPF category had little impact on associations with cardiometabolic risk factors in the US National Health and Nutrition Examination Survey 2015–2018 data sets[15]. Cut-offs for identifying high whole-grain containing foods were determined using the recent global and agreed definition of a whole-grain food developed by the Whole Grain Initiative that requires a whole-grain food to contain at least 50 % whole-grain ingredients based on dry weight, and front-of-pack labelling claims that further require foods to contain at least 25 % whole-grain ingredients based on dry weight[16]. Given the similar food supplies and intakes of UPF in Australia and the USA[17,18], it is therefore worthwhile to explore if similar results are evident in the Australian food context.

This study aimed to explore associations of UPF intake with cardiometabolic risk measures in the National Nutrition and Physical Activity Survey (NNPAS) (2011–2012) when foods with ≥ 50 and ≥ 25 % whole grains are removed from the UPF category. It is hypothesised that high whole-grain containing foods categorised as ultra-processed according to Nova do not contribute to previously established associations between high UPF intake and cardiometabolic risk measures.

Methods

Study design and population

This study included data collected on 7298 Australian adults with 1 d of valid dietary intake data in the NNPAS 2011–2012, a subcomponent of the Australian Health Survey 2011–2013. Therefore, participants were excluded from all analyses if they were < 19 years of age (*n* 2812) or under- or over-reported energy intakes based on the Goldberg cut-off of < 0·90 (*n* 2043)[19] (online Supplementary Material 1). NNPAS 2011–2012 is the most recent nationally representative cross-sectional survey of the Australian population conducted by the Australian Bureau of Statistics and includes information on demographic, socio-economic, dietary intake and health-related data of participants collected via a stratified multistage area sample of private dwellings. The accessibility and dissemination of Australian Health Survey data is governed by Section 15 of the Census and Statistics (Information Release and Access) Determination 2018 under the Census and Statistics Act 1905.

Dietary assessment

The Australian NNPAS 2011–2012 data collection methods have been previously documented[20]. Briefly, dietary intake data were collected using 24-h dietary recall assessments, on two separate occasions. The initial recall was conducted on 12 153 participants through face-to-face interviews and assistance from an adapted version of the Automated Multiple Pass Method, while the second 24-h recall was completed via telephone with a 63·6 % response rate (*n* 7735)[21]. Data analysis in the present study only included data from the 'Australian Health Survey: Nutrition and Physical Activity, 2011–2012 expanded confidentialised unit record files (CURF)' data set. Due to privacy requirements of the Australian Bureau of Statistics, online-based statistical programmes enabling predictions of usual intake were not available, and therefore, only 1 d of dietary intake data was used. Calculation of energy and nutrient compositions of foods consumed by participants in NNPAS 2011–2012 were completed using the AUSNUT 2011–2013 database[22], which provides information on 53 nutrients for 5740 foods and beverages included in the survey.

The 2011–2013 AUSNUT Nova database[18] was applied in this study to identify UPF in NNPAS 2011–2012 classified according to the Nova system, completed by linkage of food codes. The methods for Nova classification of foods and ingredients in this context are described in detail elsewhere[4,18]. Briefly, foods and beverages, including alcohol, were classified into one of the four major Nova groups (fresh or minimally processed foods, processed culinary ingredients, processed foods and UPF) via assessment of the food description and ingredient list for each AUSNUT food code corresponding to NNPAS intakes and from supporting AUSNUT data sources (Food Details File and Food Recipe File)[22]. UPF were defined as formulations of ingredients resulting from a series of industrial processes and were identified by the presence of protein isolates, modified starches, hydrogenated or interesterified oils, colourants, flavourings, artificial sweeteners, emulsifiers and various bleaching, bulking and firming agents in food descriptions or ingredient lists[18]. For food items considered to be culinary preparation or handmade recipes, Nova classification was assigned to disaggregated ingredients of recipes.

The updated Australian whole-grain database[23], an expansion of the AUSNUT 2011–2013 database[22], provides amounts of whole grain as grams per 100 g of food weight and was used in the present study to calculate intakes as grams per d. Whole-grain content based on dry weight was previously calculated for this database[24] and utilised in the present study to identify foods high in whole grain. Details of calculation methods are described elsewhere[23,24]. In the present study, whole-grain intake was calculated as grams per d and further adjusted for daily energy intake to accommodate for variations of total intakes across age and sex and was reported as grams per 10 MJ per d (g/10 MJ per d).

Dietary exposure

UPF intake in our analysis was defined as the percentage of total energy intake from UPF, with UPF defined according to the Nova definition and with high whole-grain foods removed. Therefore,

three approaches were constructed to account for the primary exposure of UPF intake:

- Approach 1 (Nova UPF): Energy contributed by UPF when original Nova classifications of UPF are applied[4].
- Approach 2 (UPF modification 1): Energy contributed by UPF when foods containing ≥ 25 % whole grains are excluded from the UPF category[16].
- Approach 3 (UPF modification 2): Energy contributed by UPF when foods containing ≥ 50 % whole grains are excluded from the UPF category[16].

Full list of all UPF that are containing ≥ 25 and ≥ 50 % whole grains based on dry weight is available in online Supplementary Materials 2 and 3, respectively.

Health outcome measures

Weight (kg), height (cm) and waist circumference (cm) of participants were obtained within the NNPAS 2011–2012 by trained interviewers and measured using digital weight scales, a stadiometer and a metal measuring tape, respectively. Systolic and diastolic blood pressure (mmHg) were measured using an automated blood pressure monitor, also by a trained interviewer. Greater detail of the methodology of anthropometric and blood pressure data collection in NNPAS 2011–2012 is described elsewhere[20]. Biochemical data were collected within the National Health Measures Survey 2011–2012. The National Health Measures Survey obtained blood and spot urine samples from a subsample of participants in the NNPAS 2011–2012 and National Health Survey 2011–2012 to measure specific biomarkers for chronic disease and nutrition status. Biochemical measures of interest include total cholesterol (mmol/l), HDL-cholesterol (mmol/l) and LDL-cholesterol (mmol/l), fasting TAG (mmol/l), fasting plasma glucose (mmol/l), glycated Hb (HbA1c) (%) and C-reactive protein (mg/l). Recordings for LDL-cholesterol, TAG and fasting plasma glucose were only obtained for participants who fasted for ≥ 8 h prior to the blood sample. Additional detail of each measure is discussed elsewhere[20].

Statistical analysis

For all analyses and for each approach, participants were ordered into quintiles by UPF intake, where the first quintile (Q1) contained participants with the lowest UPF intake and the last quintile (Q5) contained participants with the highest. Participant characteristics, including nutrient intakes relevant to the outcomes of interest, across each quintile were examined. Linear regression and a test for trend across quintiles, with adjustment for age and sex, was conducted for continuous variables and χ^2 tests were used for categorical variables. Separate linear regression analyses were conducted to examine associations between the quintiles of UPF intake and continuous cardiometabolic risk factors for each approach. As per assumption requirements of regression analyses, normality and descriptive statistics of each outcome of interest were examined prior to performing regressions. Linear regression for fasting TAG, fasting blood glucose, HbA1c and C-reactive protein outcomes were performed using the natural logarithm values as they failed to meet the assumption of normality, values were back transformed for interpretation. Regression models and covariates differed depending on the outcome of interest (Table 1), and for all outcomes assessed, both unadjusted and adjusted multivariable models were completed. Descriptions of covariates included in regression models are provided in online Supplementary Material 4. For both characteristic and regression analyses, adjusted means of each outcome were reported for quintiles of UPF intake across each approach with a test for linear trend. Statistical significance for all tests was set to $P < 0{\cdot}05$. A Bonferroni correction for multiple comparisons was used to assess the difference in means across quintiles with a significant difference observed at $P < 0{\cdot}005$. Adjusted R-squared values were computed to compare changes in associations across approaches for each outcome, indicating the contribution of high whole-grain foods to associations in approach 1. With the exclusion of high whole-grain foods, an increase in adjusted R-squared values would indicate that these foods have a positive impact on established associations, while a decrease suggests they contribute to poorer associations or outcomes. For each outcome of interest, graphs displaying slope differences of UPF intake and adjusted means of outcomes across approaches were computed (online Supplementary Material 5). Sample size differed by each outcome if the outcome of interest or at least one covariate from the respective model was missing (final *n* ranged from 1982 to 6003, depending on the outcome) as outcomes were analysed individually. Total cholesterol and LDL-cholesterol analyses also excluded participants taking lipid-lowering medication (*n* 557). Stata statistical software (StataCorp Stata Statistical Software: Release 17, 2021) was used for analyses. Complex survey design methods were utilised in this study, where sampling and replicate weights

Table 1. Adjusted models used in linear regression analyses for various cardiometabolic risk measures

Outcomes of interest	Covariates
Energy-adjusted whole grain	Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth and area remoteness
BMI/weight/WHR/WC	Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth and area remoteness
SBP/DBP	Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth, area remoteness, Na intake and BMI
Total cholesterol/HDL-cholesterol/LDL-cholesterol/Apo B/CRP	Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth, area remoteness, saturated fat intake, monounsaturated fat, polyunsaturated fat intake, alcohol intake and BMI
Fasting TAG	Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth, area remoteness, saturated fat intake, monounsaturated fat, polyunsaturated fat intake, added sugar intake, alcohol intake and BMI
Fasting plasma glucose/HbA1c	Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth, area remoteness, added sugar intake and BMI

CRP, C-reactive protein; DBP, diastolic blood pressure; SBP, systolic blood pressure; WC, waist circumference; WHR, waist-to-height ratio.

were applied to allow the generalisation of the results to the Australian population at the time of the survey[25]. Person-level weights were used in this study for whole-grain intake and anthropometric and blood pressure analyses, and biochemical-level weights were used for population characteristics and biochemical outcomes. Sensitivity analyses were conducted to compare cardiometabolic risk factor results from participants with 1 d of intake data *v.* an average of 2 d data only as well as all participants whether they have 1 or 2 d of intake data. An additional sensitivity analysis was completed on the primary analysis excluding individuals with type 2 diabetes (*n* 254) for relevant cardiometabolic risk measures including anthropometric outcomes, fasting TAG, fasting plasma glucose and HbA1c.

Results

Characteristics of the population

Participant characteristics and mean nutrient intakes by quintiles of UPF intake for approach 1 are shown in Table 2. An inverse association was found between UPF intake and age ($P < 0{\cdot}0001$). Intakes of energy, Na, saturated fat, polyunsaturated fat, monounsaturated fat, *trans*-fat and free sugars were all positively associated with UPF intake ($P < 0{\cdot}05$ for all). Higher UPF intake was also associated with lower fibre intake ($P < 0{\cdot}0001$) and, interestingly, with lower alcohol intake ($P = 0{\cdot}0006$). Participants with higher UPF intake were also more likely to be a current daily smoker ($P = 0{\cdot}0018$) and born in Australia ($P = 0{\cdot}0030$). These trends were consistent across Approaches 2 and 3 (online Supplementary Material 6) except there was no significant association between UPF intake and smoking in Approach 3.

Proportion of energy from ultra-processed food and whole-grain intake

The distribution of participants across UPF quintiles shifted when high whole-grain containing foods were excluded from the UPF category (online Supplementary Material 6). The median proportion of UPF intake from foods that are ≥ 25 and ≥ 50 % whole grains within the Nova UPF definition (approach 1) was 0 for all quintiles. Thus, a minority of participants had UPF intake that included foods with ≥ 25 and ≥ 50 % whole grains. Median whole-grain intakes in the lowest quintile of UPF intake were 36·9 g/10 MJ per d according to approach 1 (Table 2), shifting to 42·0 g/10 MJ per d and 41·5 g/10 MJ per d for approaches 2 and 3, respectively (online Supplementary Material 6). In the highest quintile of UPF intake (Q5) for approach 1, whole-grain intakes were 11·6 g/10 MJ per d, again shifting to 4·0 g/10 MJ per d in approach 2 and 4·5 g/10 MJ per d in approach 3.

Associations with cardiometabolic risk measures

The cross-sectional associations between UPF intake for all three approaches and cardiometabolic risk measures are shown in Table 3. Positive associations were found between UPF intake and body weight, BMI, waist circumference and WHR for all three approaches in adjusted models. For approach 1, participants in the highest quintile of UPF intake, compared with those in the lowest (Q1), had a higher body weight (Q5 78·1 kg; Q1 75·1 kg), BMI (Q5 27·2 kg/m^2; Q1 26·1 kg/m^2), waist circumference (Q5 92·7 cm; Q1 90·1 cm) and WHR (Q5 0·6; Q1 0·5, all $P < 0{\cdot}0001$). Mean values of each outcome and associations remained similar and significant when ≥ 25 % whole-grain UPF and ≥ 50 % whole-grain UPF were excluded in approaches 2 and 3, respectively.

For all three approaches, UPF intake was inversely associated with systolic blood pressure, total cholesterol, HDL-cholesterol and HbA1c in unadjusted models ($P < 0{\cdot}0001$ for all) (online Supplementary Material 7). Associations to all other cardiometabolic risk factors were not significant when unadjusted for covariates ($P > 0{\cdot}05$ for all). When adjusted for covariates, no significant associations remained ($P \geq 0{\cdot}05$ for all).

Results for all sensitivity analyses, including utilising an average of 2 d of dietary intake data, as well as 1 d and an average of 2 d of dietary intake data combined, and excluding individuals with type 2 diabetes from the primary analysis, did not differ substantially and remained robust (online Supplementary Materials 8, 9 and 10, respectively).

Finally, adjusted R-squared values were low for all associations of UPF intake and cardiometabolic risk outcomes. These low associations remained relatively unchanged for all outcomes and with the application of the cut points in the whole-grain modified UPF approaches.

Discussion

This study is a nationally representative cross-sectional exploration of the associations of UPF intake, among Australian adults, with cardiometabolic risk measures when high whole-grain containing foods are excluded from the Nova UPF category. Results found that higher consumption of UPF was significantly associated with higher anthropometric risk measures including body weight, BMI, waist circumference and WHR ($P < 0{\cdot}05$ for all) with and without including high whole-grain containing foods in this category. This is consistent with previous Australian research reporting on UPF associations[26] and aligns with our findings using the US National Health and Nutrition Examination Survey 2015–2018 Nova data set[15].

In the present study, adjusted R-squared values were first low across all outcomes of interest, indicating that a low proportion of each outcome is explained by the categorisation as ultra-processing. Second, adjusted R-squared values, as well as mean values of each outcome and significance of associations, remained relatively unchanged for all outcomes across all approaches. This is not surprising due to the overall low energy contributions from high whole-grain foods to total energy intake of UPF. Given this, impacts of these foods, whether that be proposed negative impacts of processing or positive impacts of whole grains related to health, are likely negligible in the present study. Previous research has concluded however that consumption of ultra-processed cereals and ultra-processed dark breads and whole-grain breads is health protective as they are significantly associated with a 22 and 4 % lower risk of type 2 diabetes[12], respectively. An additional multinational study on the EPIC cohort also found a 3 % decrease in risk of cancer-cardiometabolic multimorbidity with intake of ultra-processed breads and cereals[11], further highlighting the health benefit associated with their intake despite processing levels.

Interestingly, a key characteristic of UPF is said to include their hyper-palatability leading to excess consumption[27]. Grain products are identified as hyperpalatable according to research that developed a quantitative definition of hyperpalatable foods; however, there was no distinction made between refined and whole grains[28]. Sensory-specific satiety is the process by which the pleasantness of a food being consumed declines during an eating occasion, thus regulating feeding cessation, and underpins the

Table 2. Whole grain and nutrient intakes and characteristics of participants in NNPAS 2011–2012 by quintiles of proportion of energy from ultra-processed food in approach 1 (19+ years) (*n* 2448)

	Proportion of energy from UPF (%)										
	Q1		Q2		Q3		Q4		Q5		*P*†
Approach 1											
*n**	521		519		492		454		462		–
Proportion of energy from UPF (%) (IQR)	28·9	20·7–35·6	47·3	43·4–49·9	58·9	56·3–61·9	70·2	67·1–73·2	84·8	80·5–90·1	–
Median proportion of energy from ≥ 25 % WG UPF (%) (IQR)	0	0–3·6	0	0–7·6	0	0–6·9	0	0–6·9	0	0–7·4	–
Median proportion of energy from ≥ 50 % WG UPF (%) (IQR)	0	0–1·9	0	0–5·8	0	0–5·1	0	0–4·6	0	0–5·7	–
Median whole-grain intake (g/10 MJ per d) (IQR)	36·9	0–82·3	39·2	9·2–68·7	36·0	5·6–66·3	24·9	0–52·7	11·6	0–39·7	–
Age‡,§	48·6	$1·2^{B}$	46·7	$1·0^{B}$	43·7	$1·2^{AB}$	40·7	$1·3^{A}$	39·2	$1·1^{A}$	< 0·0001
Female (%)‖‖	52·2	$2·7^{A}$	51·0	$3·6^{A}$	51·2	$4·3^{A}$	44·7	$3·8^{A}$	49·4	$3·2^{A}$	0·5995
Energy intake (kJ/d)‡,¶	9337	177^{A}	9767	241^{AB}	10 134	225^{B}	10 246	256^{AB}	10 617	235^{B}	0·0001
Fibre intake (g/d)‡,¶	27·7	$1·1^{B}$	27·5	$0·7^{B}$	27·1	$0·9^{B}$	24·4	$0·9^{AB}$	23·8	$0·8^{A}$	< 0·0001
Na intake (mg/d)‡,¶	2130	118^{A}	2508	78^{AB}	2819	82^{BC}	3082	129^{C}	3239	130^{C}	< 0·0001
Saturated fat intake (g/d)‡,¶	26·0	$0·9^{A}$	29·8	$1·1^{AB}$	33·6	$1·1^{BC}$	37·2	$1·5^{C}$	38·4	1·4	< 0·0001
Polyunsaturated fat intake (g/d)‡,¶	12·8	$0·6^{A}$	13·3	$0·5^{AB}$	13·9	$0·5^{AB}$	13·6	$0·5^{AB}$	15·3	$0·7^{B}$	0·0100
Monounsaturated fat intake (g/d)‡,¶	30·2	$1·3^{A}$	31·7	$1·0^{AB}$	34·4	$1·1^{AB}$	34·7	$1·3^{AB}$	36·4	$1·4^{B}$	0·0003
Trans-fat intake (mg/d)‡,¶	1234	64·0	1514	$76·2^{A}$	1697	$86·3^{AB}$	1819	$93·6^{AB}$	1951	$114·0^{B}$	< 0·0001
Free sugar intake (% energy)‡,¶	7·2	$0·3^{A}$	8·5	$0·5^{A}$	10·5	$0·4^{B}$	11·6	$0·6^{B}$	14·3	0·5	< 0·0001
Alcohol intake (g/d)‡,¶	25·0	$3·4^{C}$	20·2	$2·3^{BC}$	13·5	$1·5^{AB}$	13·6	$1·7^{ABC}$	10·1	$2·2^{A}$	0·0006
University graduate (%)‖	25·3	$3·0^{A}$	23·4	$2·6^{A}$	21·9	$3·7^{A}$	21·6	$3·2^{A}$	22·0	$3·6^{A}$	0·2447
Current smoker daily (%)‖	8·0	$1·8^{A}$	9·7	$2·1^{A}$	7·6	$1·7^{A}$	12·1	$2·1^{A}$	16·8	$2·8^{A}$	0·0018
Low physical activity level (%)‖	32·5	$3·1^{A}$	29·1	$2·6^{A}$	39·6	$2·8^{A}$	40·1	$3·4^{A}$	31·7	$3·8^{A}$	0·2624
Born in Australia (%)‖	52·9	$3·7^{A}$	66·9	$3·5^{AB}$	67·0	$4·3^{AC}$	70·6	$3·9^{BC}$	71·3	$4·1^{BC}$	0·0030
Inner regional living in Australia (%)‖	17·2	$2·2^{A}$	17·7	$2·1^{A}$	20·7	$2·8^{A}$	18·1	$3·0^{A}$	15·7	$2·2^{A}$	0·4339
Lowest 10 % SEIFA ranking (%)‖	8·0	$2·0^{A}$	8·8	$1·8^{A}$	4·6	$1·2^{A}$	8·8	$2·7^{A}$	10·8	$3·3^{A}$	0·9374

SEIFA, National Index of Relative Socio-economic Disadvantage 2011; UPF, ultra-processed food; WG, whole grain.
**n* (unweighted) is based on participants 19 years and over within the NNPAS 2011–2012 that have complete information for all characteristics of interest.
†Associations with continuous variables were determined through a test for trend post-linear regression. Associations with categorical variables were determined through Pearson's χ^2 analysis. Significance is determined at $P < 0·05$.
‡Reported as $\bar{x}$ (SEM).
§Linear regression adjusted for sex.
‖Reported as percentage (SE).
¶Linear regression adjusted for age and sex.
Categories sharing capital letters within rows are not statistically significant from each other. Comparison of means were conducted through pairwise comparison. Comparison of percentages were conducted through individual Pearson's χ^2 analysis. All comparisons applied a Bonferroni correction for multiple comparisons such that a significant difference was observed at $P < 0.005$. Some significance is lost between categories when applying Bonferroni correction.

Table 3. Association between quintiles of energy intake (%E) from ultra-processed food (UPF) and cardiometabolic risk measures for whole-grain modified UPF definitions in Australian adults with 1d of intake

	Proportion of energy intake from UPF (%)*												
	Q1		Q2		Q3		Q4		Q5		P for linear trend†	P for sig. difference‡	Adjusted R-squared
	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM			
Energy-adjusted WG intake (g/10 MJ per d)§ (*n* 4461)													
Adjusted													
Approach 1	46·2	1·2	36·7	1·2	37·1	$1·2^{A}$	31·6	$1·2^{A}$	21·1	1·2	< 0·0001	< 0·0001	0·0841
Approach 2	54·9	1·2	43·4	$1·2^{A}$	37·7	$1·2^{A}$	29·9	1·2	15·7	1·2	< 0·0001	< 0·0001	0·1542
Approach 3	54·3	1·3	41·8	$1·2^{A}$	38·8	$1·2^{A}$	29·8	1·2	16·0	1·2	< 0·0001	< 0·0001	0·1473
Body weight (kg)§ (*n* 6003)													
Adjusted													
Approach 1	75·1	$0·6^{A}$	75·9	$0·6^{AB}$	76·8	$0·6^{AB}$	76·9	$0·6^{AB}$	78·1	$0·6^{B}$	0·0003	0·0116	0·2235
Approach 2	74·8	$0·6^{A}$	76·5	$0·7^{AB}$	76·5	$0·6^{AB}$	77·2	$0·6^{B}$	77·8	$0·6^{B}$	0·0007	0·0077	0·2236
Approach 3	75·0	$0·6^{A}$	76·2	$0·6^{AB}$	76·4	$0·5^{AB}$	77·1	$0·6^{AB}$	78·1	$0·6^{B}$	0·0007	0·0122	0·2236
BMI (kg/m^2)§ (*n* 5970)													
Adjusted													
Approach 1	26·1	$0·2^{A}$	26·5	$0·2^{AB}$	26·7	$0·2^{AB}$	26·7	$0·2^{AB}$	27·2	$0·2^{B}$	0·0001	0·0010	0·0912
Approach 2	26·1	$0·2^{A}$	26·6	$0·2^{AB}$	26·6	$0·2^{AB}$	26·8	$0·2^{AB}$	27·2	$0·2^{B}$	0·0001	0·0017	0·0908
Approach 3	26·1	$0·2^{A}$	26·6	$0·2^{AB}$	26·6	$0·2^{AB}$	26·8	$0·2^{AB}$	27·2	$0·2^{B}$	0·0001	0·0015	0·0913
Waist circumference (cm)§ (*n* 5901)													
Adjusted													
Approach 1	90·1	$0·5^{A}$	90·9	$0·5^{AB}$	91·7	$0·5^{AB}$	91·3	$0·5^{AB}$	92·7	$0·5^{B}$	0·0006	0·0071	0·2577
Approach 2	90·1	$0·5^{A}$	91·0	$0·5^{AB}$	91·2	$0·4^{AB}$	91·7	$0·5^{AB}$	92·7	$0·6^{B}$	0·0002	0·0066	0·2577
Approach 3	90·2	$0·4^{A}$	90·8	$0·5^{AB}$	91·3	$0·4^{AB}$	91·7	$0·4^{AB}$	92·7	$0·6^{B}$	0·0002	0·0078	0·2577
Waist:height ratio§ (*n* 5875)													
Adjusted													
Approach 1	0·53	$0·003^{A}$	0·54	$0·003^{AB}$	0·54	$0·003^{AB}$	0·54	$0·003_{AB}$	0·55	$0·003^{B}$	0·0004	0·0045	0·2240
Approach 2	0·53	$0·003^{A}$	0·54	$0·003^{AB}$	0·54	$0·003^{AB}$	0·54	$0·003^{AB}$	0·55	$0·004^{B}$	0·0002	0·0065	0·2237
Approach 3	0·53	$0·002^{A}$	0·54	$0·003^{AB}$	0·54	$0·003^{AB}$	0·54	$0·003^{AB}$	0·55	$0·004^{B}$	0·0001	0·0052	0·2239
Systolic blood pressure (mmHg)‖ (*n* 5787)													
Adjusted													
Approach 1	122·1	$0·6^{A}$	123·4	$0·9^{A}$	122·2	$0·6^{A}$	122·8	$0·6^{A}$	121·2	$0·6^{A}$	0·2384	0·2128	0·2778
Approach 2	121·9	$0·7^{A}$	123·7	$0·9^{A}$	122·1	$0·5^{A}$	122·5	$0·7^{A}$	121·4	$0·6^{A}$	0·2860	0·0660	0·2781
Approach 3	122·0	$0·6^{A}$	123·9	$0·9^{A}$	121·7	$0·6^{A}$	122·8	$0·6^{A}$	121·3	$0·6^{A}$	0·2255	0·0447	0·2786

https://doi.org/10.1017/S0007114524002952 Published online by Cambridge University Press

Table 3. (*Continued*)

Diastolic blood pressure (mmHg)‖ (*n* 5787)													
Adjusted													
Approach 1	75·9	0·4[A]	76·8	0·5[A]	76·2	0·4[A]	76·1	0·4[A]	75·6	0·4[A]	0·2963	0·3713	0·1364
Approach 2	75·8	0·4[A]	76·8	0·5[A]	75·9	0·4[A]	76·2	0·4[A]	75·8	0·4[A]	0·6559	0·4339	0·1363
Approach 3	75·8	0·4[A]	76·8	0·5[A]	75·9	0·4[A]	76·5	0·4[A]	75·5	0·4[A]	0·5307	0·2743	0·1369
Total cholesterol (mmol/l)¶ (*n* 2424)													
Adjusted													
Approach 1	5·2	0·1[A]	5·1	0·1[A]	5·1	0·1[A]	5·0	0·1[A]	5·1	0·1[A]	0·5071	0·7379	0·1375
Approach 2	5·2	0·1[A]	5·1	0·1[A]	5·1	0·1[A]	5·1	0·1[A]	5·1	0·1[A]	0·4158	0·8699	0·1365
Approach 3	5·2	0·1[A]	5·1	0·1[A]	5·1	0·1[A]	5·03	0·1[A]	5·1	0·1[A]	0·4656	0·8502	0·1369
Fasting LDL-cholesterol (mmol/l)¶ (*n* 1982)													
Adjusted													
Approach 1	3·3	0·1[A]	3·2	0·1[A]	3·1	0·1[A]	3·2	0·1[A]	3·2	0·1[A]	0·5167	0·5880	0·1733
Approach 2	3·7	0·1[A]	3·2	0·1[A]	3·2	0·1[A]	3·1	0·1[A]	3·2	0·1[A]	0·4740	0·5873	0·1734
Approach 3	3·3	0·1[A]	3·1	0·1[A]	3·2	0·04[A]	3·1	0·1[A]	3·2	0·1[A]	0·6387	0·4455	0·1740
HDL-cholesterol (mmol/l)¶ (*n* 2842)													
Adjusted													
Approach 1	1·4	0·02[A]	1·4	0·02[A]	1·4	0·02[A]	1·4	0·02[A]	1·3	0·02[A]	0·7707	0·5327	0·2707
Approach 2	1·3	0·02[A]	1·4	0·02[A]	1·4	0·02[A]	1·4	0·02[A]	1·3	0·02[A]	0·7163	0·0921	0·2738
Approach 3	1·3	0·02[A]	1·4	0·02[A]	1·4	0·02[A]	1·4	0·02[A]	1·4	0·02[A]	0·8771	0·4532	0·2713
Fasting TAG (mmol/l)** (*n* 2418)													
Adjusted													
Approach 1	1·1	1·0[A]	1·1	1·0[A]	1·1	1·0[A]	1·1	1·0[A]	1·1	1·0[A]	0·9230	0·7037	0·2187
Approach 2	1·1	1·0[AB]	1·0	1·0[A]	1·2	1·0[B]	1·1	1·0[AB]	1·1	1·0[AB]	0·6553	0·0499	0·2232
Approach 3	1·1	1·0[A]	1·1	1·0[A]	1·2	1·0[A]	1·1	1·0	1·1	1·0[A]	0·7551	0·3903	0·2206
Fasting plasma glucose (mmol/l)†† (*n* 2418)													
Adjusted													
Approach 1	5·0	1·0[A]	5·0	1·0[A]	5·0	1·0[A]	5·0	1·0[A]	5·0	1·0[A]	0·5201	0·9384	0·2556
Approach 2	5·0	1·0[A]	5·0	1·0[A]	5·0	1·0[A]	5·0	1·0[A]	5·0	1·0[A]	0·9007	0·7479	0·2564
Approach 3	5·0	1·0[A]	5·0	1·0[A]	5·0	1·0[A]	5·0	1·0[A]	5·0	1·0[A]	0·6609	0·9329	0·2557
HbA1c (%)†† (*n* 2833)													
Adjusted													
Approach 1	5·4	1·0[A]	5·4	1·0[A]	5·4	1·0[A]	5·4	1·0[A]	5·4	1·0[A]	0·5548	0·4878	0·2586

(*Continued*)

https://doi.org/10.1017/S0007114524002952 Published online by Cambridge University Press

Table 3. (*Continued*)

	Proportion of energy intake from UPF (%)*												
	Q1		Q2		Q3		Q4		Q5		P for linear trend†	P for sig. difference‡	Adjusted R-squared
	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM			
Approach 2	5·4	1·0^{A}	5·4	1·0^{A}	5·4	1·0^{A}	5·4	1·0^{A}	5·4	1·0^{A}	0·5022	0·4246	0·2590
Approach 3	5·4	1·0^{A}	5·4	1·0^{A}	5·4	1·0^{A}	5·5	0·04^{A}	5·4	1·0^{A}	0·4286	0·1654	0·2613
Apo B (g/l)¶ (*n* 2423)													
Adjusted													
Approach 1	1·0	0·02^{A}	1·0	0·02^{A}	1·0	0·02^{A}	1·0	0·02^{A}	1·0	0·02^{A}	0·3585	0·5395	0·1588
Approach 2	1·0	0·02^{A}	1·0	0·02^{A}	1·0	0·02^{A}	1·0	0·02^{A}	1·0	0·02^{A}	0·4703	0·6142	0·1587
Approach 3	1·0	0·02^{A}	1·0	0·02^{A}	1·0	0·01^{A}	1·0	0·02^{A}	1·0	0·02^{A}	0·4526	0·7077	0·1581
C-reactive protein (mg/l)¶ (*n* 2840)													
Adjusted													
Approach 1	1·5	1·0^{A}	1·3	1·0^{A}	1·32	1·0^{A}	1·41	1·0^{A}	1·5	1·0^{A}	0·6677	0·1746	0·2582
Approach 2	1·5	1·0^{A}	1·3	1·0^{A}	1·36	1·0^{A}	1·32	1·0^{A}	1·6	1·0^{A}	0·5373	0·0486	0·2596
Approach 3	1·5	1·0^{A}	1·3	1·0^{A}	1·39	1·0^{A}	1·42	1·0^{A}	1·5	1·0^{A}	0·5778	0·0687	0·2583

Quintiles sharing capital letters within rows are not statistically significant from each other. Comparison of means were conducted through pairwise comparison. All comparisons applied a Bonferroni correction or multiple comparisons such that a significant difference was observed at $P < 0·005$.

*Values are reported as $\bar{x}$ | SEM.

†*P*-value for linear trend. A significance is determined at $P < 0·05$.

‡*P*-value for significant difference determined through test for equality of means. Significance is determined at $P < 0·05$.

§Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth and area remoteness.

||Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth, area remoteness, Na intake and BMI.

¶Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth, area remoteness, saturated fat intake, monounsaturated fat, polyunsaturated fat intake, *trans*-saturated fat intake, alcohol intake and BMI.

**Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth, area remoteness, saturated fat intake, monounsaturated fat, polyunsaturated fat intake, *trans*-saturated fat intake, free sugar intake, alcohol intake and BMI.

††Age, sex, education, physical activity level, smoking status, socio-economic status, country of birth, area remoteness, free sugar intake and BMI.

Categories sharing capital letters within rows are not statistically significant from each other. Comparison of means were conducted through pairwise comparison. Comparison of percentages were conducted through individual Pearson's χ^2 analysis. All comparisons applied a Bonferroni correction for multiple comparisons such that a significant difference was observed at $P < 0.005$. Some significance is lost between categories when applying Bonferroni correction.

theory of combined ingredients creating hyperpalatable[29]. For breads as an example, differentiation between refined and whole wheat varieties has shown significant differences in sensory-specific satiety responses, such that it is weaker for white bread when compared with whole wheat[30]. In the present study, it is also evident that whole-grain UPF varieties are not consumed in excess, therefore also not fitting the hyperpalatable rhetoric. Whole-grain consumption more broadly in the Australian population is consistently low, where almost three-quarters of the population do not meet recommendations[9]. Therefore, any messaging regarding foods with higher whole-grain content should consider the potential impacts on existing low intakes and advocacy efforts.

No association was found between consumption of UPF and biochemical risk measures when using the Nova UPF definition for this cohort. The same findings were present when high whole-grain containing UPF were excluded from this food category. These findings are somewhat consistent with another study exploring UPF intake and lipid profiles, where no associations were evident for any lipid outcomes other than TAG and HDL-cholesterol, where UPF intake was associated with higher odds of abnormality[31]. Previous research has also reported associations of higher C-reactive protein alongside higher UPF intake; however, these findings are not consistent with the present study, and confounding of BMI as well as directionality of the observed associations was not clear[15,32]. Currently, the evidence regarding contribution of UPF intake to increased risk of impaired biochemical health measures is not definitive.

The robustness of food ultra-processing as a driving factor of poor health and worsened disease outcomes is of increasing interest throughout recent literature. This is primarily due to the mediation of observed associations, as in the present study, by diet quality. This is because UPF intake is associated with both a deterioration in diet quality and positively with cardiometabolic risk[33]. Previous attempts of controlling for diet quality, by matching energy and nutrient content from an ultra-processed to a non-ultra-processed diet, still failed to match food portions, and thus the results finding an increase of 0·9 kg in weight with higher UPF intake was in fact mostly attributable to higher energy consumption[34]. It is also worthy to note that grain-based UPF offered to participants in this trial were 'white' or refined and did not include any whole grains. Greater evidence quality and long-term intervention studies are required to confirm causality of associations.

Importantly, broad statements recommending for exclusion of UPF in the diet should be avoided based on the current anomalous evidence as it may have unintended consequences on nutrient intakes as summarised well in the position statement of the British Nutrition Foundation[35]. This statement specifically mentioned the ability of ready-to-eat cereals and breads and bread rolls that are considered ultra-processed to contribute to a healthy balanced diet, especially for at-risk populations. Impacts on nutrient intakes, if said foods are excluded, are of even more concern in the Australian food context due to the mandatory fortification of bread-making flour with nutrients including thiamine and folic acid and iodine in salt also as part of commercial bread production[36]. This policy introduction was to combat increasing prevalence of conditions associated with said nutrient deficiencies, with success, one example being neural tube defects[14]. Since the introduction of mandatory fortification in Australia, neural tube defects have fallen by 14 % in the general population and 74 % in Indigenous women[13]. Blunt recommendations to limit intakes of UPF may have negative impacts on nutrient accessibility as well as energy intakes more broadly. Some at-risk communities in Australia, such as low socio-economic communities, rely on the 'ultra'-processing of such foods for access to energy intake that is shelf stable and safe[37,38]. Therefore, the promotion of 'ultra'-processed energy sources that also provide essential nutrients, like whole-grain breads and cereals, should not be discouraged particularly in this context.

The mechanisms underlying associations between UPF consumption and poor health outcomes are not yet conclusive; however, available evidence suggests differential aspects compared with their unprocessed or minimally processed counterparts exist. These include poorer nutrient profiles, displacement of non-UPF in dietary patterns and changes to the physical and chemical structure of foods because of ultra-processing[39]. The present study found that higher UPF intake was associated with higher intakes of energy, saturated fat, added sugar and Na and lower fibre, which are all typical characteristics of UPF[18]. Contrary to this, whole-grain consumption is linked with improved nutrient intakes including higher fibre and micronutrient intakes, as well as lower Na intake[40]. Therefore, whole-grain varieties of UPF do not reflect or fit with typical UPF characteristics. Additionally, mandatory fortification of commercial bread-making flour in Australia further misaligns high whole-grain foods considered ultra-processed with the description of UPF as 'energy dense and nutrient poor'. Fortification should also be considered in the context of the displacement of non-ultra-processed and nutrient-rich foods with UPF. Previous dietary modelling shows that substitution of whole-grain foods considered UPF with their non-ultra-processed counterpart significantly decreased key nutrient intakes, primarily due to fortification[41]. Key nutrients could be replaced with carefully selected substitutes; however, deviation from convenience and customary food choices reduces likeness of this being successful[41]. Finally, processing impacts on the food matrix is suggested to affect digestion, nutrient absorption and satiation; however, greater research is required to explain these theories[42].

Limitations are present in the present study. Although the NNPAS 2011–2012 is the most recent nationally representative data available in Australia, it is important to recognise that it is greater than 10 years old, and current intakes in Australia may be different. However, due to the comparative methods of this study, the data are still appropriate to use. Additionally, the cross-sectional nature of the study design also limits results found to infer correlations only. Although evidence supports beneficial cross-sectional associations of anthropometric outcomes and health behaviours with whole-grain consumption, reverse causation in this study cannot be ruled out. Like most nationally representative surveys, dietary data collection methods used in NNPAS 2011–2012 are limited to estimation of intakes and may not reflect true intakes particularly as only 1 d of dietary data was used in the main analysis of the present study. For rigorous reporting of intakes, literature recommends at least four 24-h recalls is required to capture usual intake[43]. However, sensitivity analyses performed showed negligible differences in cardiometabolic risk measure results when using 1 d of dietary intake data *v.* only 2 d data as well as 1 d and 2 d combined. This study is also limited by misreporting bias inherent in 24-h recalls as participants often underreport intakes of foods considered unhealthy. Application of the Goldberg cut-off was done in this study to control for this. The statistical significance of across quintiles comparisons were considered after adjustment for multiple comparisons were made; however, adjustments were not made for multiple outcomes, and the results

should be interpreted in this context. Finally, the researchers who developed the AUSNUT 2011–2013 Nova database have acknowledge that the design of this food composition database was not intended to consider industrial processing, and thus, some misclassification of foods into Nova categories may be present[18].

This study has several strengths. First, due to the use of survey weighting in the study methods, results from this study are generalisable to the Australian population at the time of the survey. It is also the first study to consider the contribution of whole grains to previously determined associations of UPF intake in the Australian context. Finally, this study strengthens the evidence recommending further considerations to be addressed prior to the endorsement of Nova in any national guidelines.

This study found that the impacts of high whole-grain foods considered ultra-processed on cardiometabolic risk measures may be negligible as associations remained relatively unaffected with their exclusion from the UPF category. Based on the inconsistencies of the evidence regarding the health impacts of food processing, particularly for commercial whole-grain bread and ready-to-eat cereal varieties, the umbrella recommendation of discouraging UPF intake is not justified. This subgroup of foods may exist as part of a balanced diet that provides essential nutrients, especially due to mandatory fortification initiatives in Australia. As they are not mutually exclusive, greater consideration of the nutrient profiles of these whole-grain foods in conjunction with greater evidence regarding the impacts of processing they undergo is required prior to any consideration of Nova in dietary advice and policy action.

Acknowledgements. We acknowledge the use of the AUSNUT 2011–2013 Nova database approved by the Center for Epidemiological Research in Nutrition and Health/University of São Paulo.

No funding was received for this study.

The author's contributions were as follows – E. J. P., K. R. K., E. M. B., M. J. B. and E. J. B. designed the research; E. J. P. conducted the research, analysed the data and wrote the initial draft of manuscript; E. J. B. provided essential materials; E. J. P., K. R. K., E. M. B., M. J. B. and E. J. B. reviewed and edited the manuscript; E. J. B. had primary responsibility for the final content, and all authors read and approved the final manuscript.

The authors report no conflicts of interest for the submitted work. E. J. P., K. R. K., E. M. B. and E. J. B. are unpaid members of the Whole Grain Intake Recommendation Working Party of the Whole Grain Initiative.

Ethics approval was not required for this study. The accessibility and dissemination of Australian Health Survey data is governed by Section 15 of the Census and Statistics (Information Release and Access) Determination 2018 under the Census and Statistics Act 1905.

Data described in the manuscript, codebook and analytic code will be made available upon request, pending application and approval.

Supplementary material. For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114524002952.

References

1. Australian Institute of Health and Welfare (2023) Chronic Conditions and Multimorbidity. https://www.aihw.gov.au/reports/australias-health/chronic-conditions-and-multimorbidity (accessed May 2024).
2. Australian Institute of Health and Welfare (2019) Poor Diet. https://www.aihw.gov.au/reports/food-nutrition/poor-diet/contents/dietary-guidelines (accessed May 2024).
3. National Health and Medical Research Council (2013) Australian Dietary Guidelines. https://www.eatforhealth.gov.au/guidelines (accessed May 2024).
4. Monteiro CA, Cannon G, Levy R, *et al.* (2016) NOVA. The star shines bright. (Food classification public health). *World Nutr* **7**, 28–38.
5. Mambrini SP, Menichetti F, Ravella S, *et al.* (2023) Ultra-processed food consumption and incidence of obesity and cardiometabolic risk factors in adults: a systematic review of prospective studies. *Nutrients* **15**, 2583.
6. Jardim MZ, de Lima Costa BV, Pessoa MC, *et al.* (2021) Ultra-processed foods increase noncommunicable chronic disease risk. *Nutr Res* **95**, 19–34.
7. Nguyen H, Jones A, Barrett EM, *et al.* (2024) Extent of alignment between the Australian Dietary Guidelines and the NOVA classification system across the Australian packaged food supply. *Nutr Diet* 2024, 1–11.
8. Grech A, Rangan A, Allman-Farinelli M, *et al.* (2022) A comparison of the Australian Dietary Guidelines to the NOVA classification system in classifying foods to predict energy intakes and Body Mass Index. *Nutrients* **14**, 3942.
9. Galea LM, Beck EJ, Probst YC, *et al.* (2017) Whole grain intake of Australians estimated from a cross-sectional analysis of dietary intake data from the 2011–2013 Australian Health Survey. *Public Health Nutr* **20**, 2166–2172.
10. Aune D, Keum N, Giovannucci E, *et al.* (2016) Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: systematic review and dose-response meta-analysis of prospective studies. *BMJ* **353**, i2716.
11. Cordova R, Viallon V, Fontvieille E, *et al.* (2023) Consumption of ultra-processed foods and risk of multimorbidity of cancer and cardiometabolic diseases: a multinational cohort study. *Lancet Regional Health – Eur* **35**, 100771.
12. Chen Z, Khandpur N, Desjardins C, *et al.* (2023) Ultra-processed food consumption and risk of type 2 diabetes: three large prospective U.S. cohort studies. *Diabetes Care* **46**, 1335–1344.
13. Australian Institute of Health and Welfare (2016) *Folic Acid & Iodine Fortification*. Canberra: AIHW.
14. Centers for Disease Control and Prevention (CDC) (2022) Neural Tube Defects Prevention around the World. https://www.cdc.gov/ncbddd/folicacid/global-ntd-prevention.html (accessed May 2024).
15. Price EJ, Du M, McKeown NM, *et al.* (2024) Excluding whole grain-containing foods from the Nova ultraprocessed food category: a cross-sectional analysis of the impact on associations with cardiometabolic risk measures. *Am J Clin Nutr* **119**, 1133–1142.
16. van der Kamp JW, Jones JM, Miller KB, *et al.* (2021) Consensus, global definitions of whole grain as a food ingredient and of whole-grain foods presented on behalf of the whole grain initiative. *Nutrients* **14**, 138.
17. Wang L, Steele EM, Du M, *et al.* (2021) Trends in consumption of ultraprocessed foods among US youths aged 2–19 years, 1999–2018. *JAMA* **326**, 519–530.
18. Machado PP, Steele EM, Levy RB, *et al.* (2019) Ultra-processed foods and recommended intake levels of nutrients linked to non-communicable diseases in Australia: evidence from a nationally representative cross-sectional study. *BMJ Open* **9**, e029544.
19. Black AE (2000) Critical evaluation of energy intake using the Goldberg cut-off for energy intake:basal metabolic rate. A practical guide to its calculation, use and limitations. *Int J Obesity* **24**, 1119–1130.
20. Australian Bureau of Statistics (ABS) (2013) Australian Health Survey: User's Guide 2011–2013. 4363.0.55.001. https://www.abs.gov.au/ausstats/abs@.nsf/mf/4363.0.55.001 (accessed March 2024).
21. Australian Bureau of Statistics (ABS) (2014) Australian Health Survey: Nutrition First Results – Food and Nutrients 2011–2012 financial year. Australian Bureau of Statistics. https://www.abs.gov.au/statistics/health/health-conditions-and-risks/australian-health-survey-nutrition-first-results-foods-and-nutrients/latest-release (accessed March 2024).
22. Food Standards Australia New Zealand (FSANZ) (2014) AUSNUT 2011–2013. https://www.foodstandards.gov.au/science-data/food-nutrients-databases/ausnut-2011-13 (accessed May 2024).
23. Galea LM, Dalton SM, Beck EJ, *et al.* (2016) Update of a database for estimation of whole grain content of foods in Australia. *J Food Compos Anal* **50**, 23–29.
24. Kissock KR, Neale EP & Beck EJ (2020) The relevance of whole grain food definitions in estimation of whole grain intake: a secondary analysis of the National Nutrition and Physical Activity Survey 2011–2012. *Public Health Nutr* **23**, 1307–1319.

25. Birrell CL, Steel DG, Batterham MJ, *et al.* (2019) How to use replicate weights in health survey analysis using the National Nutrition and Physical Activity Survey as an example. *Public Health Nutr* **22**, 3315–3326.
26. Machado PP, Steele EM, Levy RB, *et al.* (2020) Ultra-processed food consumption and obesity in the Australian adult population. *Nutr Diabetes* **10**, 39.
27. Monteiro CA, Cannon G, Levy RB, *et al.* (2019) Ultra-processed foods: what they are and how to identify them. *Public Health Nutr* **22**, 936–941.
28. Fazzino TL, Rohde K & Sullivan DK (2019) Hyper-palatable foods: development of a quantitative definition and application to the US food system database. *Obesity* **27**, 1761–1768.
29. Rolls BJ (1986) Sensory-specific satiety. *Nutr Rev* **44**, 93–101.
30. Johnson J & Vickers Z (1991) Sensory-specific satiety for selected bread products. *J Sens Stud* **6**, 65–79.
31. Nouri M, Eskandarzadeh S, Makhtoomi M, *et al.* (2023) Association between ultra-processed foods intake with lipid profile: a cross-sectional study. *Sci Rep* **13**, 7258.
32. Lane MM, Lotfaliany M, Forbes M, *et al.* (2022) Higher ultra-processed food consumption is associated with greater high-sensitivity C-reactive protein concentration in adults: cross-sectional results from the Melbourne collaborative cohort study. *Nutrients* **14**, 3309.
33. Griffin J, Albaloul A, Kopytek A, *et al.* (2021) Effect of ultraprocessed food intake on cardiometabolic risk is mediated by diet quality: a cross-sectional study. *BMJ Nutr, Prev Health* **4**, 174.
34. Hall KD, Ayuketah A, Brychta R, *et al.* (2019) Ultra-processed diets cause excess calorie intake and weight gain: an inpatient randomized controlled trial of ad libitum food intake. *Cell Metab* **30**, 67–77.e3.
35. Foundation BN (2024) Position Statement on the Concept of Ultra-Processed Foods (UPF). https://www.nutrition.org.uk/news/position-statement-on-the-concept-of-ultra-processed-foods-upf/ (accessed May 2024).
36. Food Standards Australia New Zealand (2022) Australia New Zealand Food Standards Code – Standard 2.1.1 – Cereal and Cereal Products. https://www.legislation.gov.au/Details/F2015L00420 (accessed May 2024).
37. Coyle DH, Huang L, Shahid M, *et al.* (2022) Socio-economic difference in purchases of ultra-processed foods in Australia: an analysis of a nationally representative household grocery purchasing panel. *Int J Behav Nutr Physical Activity* **19**, 148.
38. Touvier M, da Costa Louzada ML, Mozaffarian D, *et al.* (2023) Ultra-processed foods and cardiometabolic health: public health policies to reduce consumption cannot wait. *BMJ* **383**, e075294.
39. Lane MM, Gamage E, Du S, *et al.* (2024) Ultra-processed food exposure and adverse health outcomes: umbrella review of epidemiological meta-analyses. *BMJ* **384**, e077310.
40. Mann KD, Pearce MS, McKevith B, *et al.* (2015) Whole grain intake and its association with intakes of other foods, nutrients and markers of health in the National Diet and Nutrition Survey rolling programme 2008–2011. *Br J Nutr* **113**, 1595–1602.
41. Estell ML, Barrett EM, Kissock KR, *et al.* (2022) Fortification of grain foods and NOVA: the potential for altered nutrient intakes while avoiding ultra-processed foods. *Eur J Nutr* **61**, 935–945.
42. Srour B, Kordahi MC, Bonazzi E, *et al.* (2022) Ultra-processed foods and human health: from epidemiological evidence to mechanistic insights. *Lancet Gastroenterol Hepatol* **7**, 1128–1140.
43. Holmes B, Dick K & Nelson M (2008) A comparison of four dietary assessment methods in materially deprived households in England. *Public Health Nutr* **11**, 444–456.