Scientific Advisory Committee on Nutrition

Processed foods and health: SACN's rapid evidence update

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1. Introduction

In July 2023 the Scientific Advisory Committee on Nutrition (SACN) published a position statement on processed foods and health (SACN 2023a), summarising a scoping review of the evidence on processed foods and health. The statement:

- evaluated existing classifications of processed foods, including ultra-processed foods and the NOVA classification (a food classification that categorises foods according to the extent and purpose of food processing, rather than in terms of nutrients)
- evaluated the suitability and methods to apply food processing definitions as a dietary exposure
- considered the availability and quality of evidence associating different forms or levels of food processing with health outcomes

Eight classification systems were identified and considered against a set of initial screening criteria. NOVA was the only processed food classification (including its 'ultra-processed food' (UPF) category) that met SACN's initial screening criteria as being potentially suitable for use in the UK. However, assessment of the NOVA approach identified some concerns around its practical application in the UK. In particular, the classification of some foods was discordant with nutritional and other food-based classifications. SACN noted that the research literature investigating the health impacts of processed foods was dominated by NOVA.

SACN concluded the following.

Systematic reviews (SRs) consistently reported that higher consumption of (ultra-) processed foods was associated with increased risks of adverse health outcomes (including obesity, type 2 diabetes, cardiovascular disease, depression, mortality and a range of maternal and child health outcomes). However, SACN noted there were uncertainties around the quality of the available evidence. This is because the available evidence was almost exclusively observational (and therefore unable to show causation) and confounding factors or covariates may not have been adequately accounted for.

Consumption of (ultra-) processed foods may be an indicator of other unhealthy dietary patterns and lifestyle behaviours. Diets high in (ultra-) processed foods are often energy dense, high in saturated fat, salt or free sugars, high in processed meat and low in fruit and vegetables and fibre.

It is unclear to what extent observed associations between (ultra-) processed foods and adverse health outcomes were explained by established relationships between nutritional factors and health outcomes on which SACN had undertaken robust risk assessments.

The nature of any associations between (ultra-) processed foods and health are influenced by the classification system used.

Overall SACN concluded that the association between higher consumption of (ultra-) processed foods and adverse health outcomes is concerning. The limitations in the available evidence on (ultra-) processed foods and health (as outlined above) means it is unclear whether these foods are inherently unhealthy due to processing or because a large majority of (ultra-) processed foods are high in calories, saturated fat, salt and/or free sugars.

SACN also made a number of research recommendations, including the need for further:

- assessment and development of a (ultra-) processed foods classification system that can reliably be applied to estimate consumption of processed foods in the UK
- evidence exploring relationships between (ultra-) processed foods and health outcomes
- assessment and refinement of National Diet and Nutrition Survey methodology to better estimate and monitor processed food consumption, while minimising the impact on participant burden

Given SACN's concerns, the committee added the topic of processed foods to its watching brief and committed to consider again at its horizon scan session in 2024.

This rapid update considers new evidence on the topic and whether any further assessment is warranted at this time.

2. Background

Since the publication of the SACN position statement on processed foods and health in July 2023 (SACN, 2023a), there have been a number of relevant publications.

2.1 SACN report on feeding young children aged 1 to 5 years

In July 2023, SACN published its report Feeding young children aged 1 to 5 years (SACN, 2023b). The report highlighted findings from UK dietary surveys indicating that current diets of young children in the UK do not meet dietary recommendations for several nutrients, and that intakes of energy, free sugars, protein and salt in young children exceed recommendations. Commercial baby foods are one of the main contributors to energy and free sugars intake in this age group, in children who consume these products, with consumption of sweet and savoury snack foods increasing with age.

SR evidence informing this report indicated that in young children aged 1 to 5 years:

- higher total protein intake is associated with increased body mass index (BMI) in later childhood
- higher sugar-sweetened beverage consumption is associated with increased BMI and risk of overweight and obesity in childhood
- higher child BMI or weight status is associated with higher adult BMI or risk of overweight or obesity
- higher free sugars intake is associated with increased development of dental caries in childhood and adolescence

SACN made several recommendations in relation to foods and drinks that may be classified as ultra-processed. Recommendations were that:

- UK dietary recommendations for average intake of free sugars (that free sugars intake should not exceed 5% of total dietary energy intake) should apply from the age of 1 year
- children aged 1 to 5 years should not be given sugar-sweetened beverages (SSBs)
- dairy products (such as yoghurts and fromage frais) given to children aged 1 to 5 years should ideally be unsweetened
- formula milks (including infant formula, follow-on formula, 'growing-up' or other toddler milks) are not required by children aged 1 to 5 years
- foods (including snacks) that are energy dense and high in saturated fat, salt or free sugars should be limited in children aged 1 to 5 years
- commercially manufactured foods and drinks marketed specifically for infants and young children are not needed to meet nutritional requirements

SACN recommended that government consider strategies to reduce consumption of:

- free sugars and excess protein in children aged 1 to 5 years
- foods (including snacks) that are energy dense and high in saturated fat, salt and free sugars in children aged 1 to 5 years, while encouraging uptake of healthier snacks
- sugar-sweetened beverages in children aged 1 to 5 years

Government has accepted SACN's recommendations. Relevant webpages on the NHS website and Better Health: Start for Life website have been updated to reflect the updated advice, and the Eatwell Guide has been amended.

The National Institute for Health and Care Research (NIHR) has published a research call on early years nutrition following SACN's recommendations for further research.

2.2 World Health Organization guideline on non-sugar sweeteners

All foods containing non-sugar sweeteners (NSS) are classified as UPF under the NOVA definition.

In May 2023, the World Health Organization (WHO) guideline Use of non-sugar sweeteners stated:

> "non-sugar sweeteners (NSS) not be used as a means of achieving weight control or reducing the risk of noncommunicable diseases."

WHO defines NSS as "all synthetic and naturally occurring or modified non-nutritive sweeteners that are not classified as sugars". The guideline also states NSS can also be referred to as "high-intensity sweeteners, low or no-calorie sweeteners, non-nutritive sweeteners, non-caloric sweeteners and sugar substitutes". This definition did not include caloric or bulk NSS such as polyols.

The guideline highlights that there continues to be uncertainties in the evidence base on sweeteners and the role they may play in supporting weight management. The assessment reported that:

> "evidence from a recent systematic review and meta-analyses of randomized controlled trials (RCTs) and prospective observational studies found that higher NSS consumption by adults led to lower body weight and BMI, compared with not consuming NSS or consuming lower amounts of NSS, when assessed in short-term RCTs, but was associated with increased BMI and risk of incident obesity in long-term prospective observational studies."

SACN has reviewed the WHO guideline and associated evidence, and has made a number of recommendations within its 2025 position statement (SACN, 2025).

SACN members have previously noted the importance of collecting information on trends and intake of NSS due to potential increases in use, resulting from dietary public health policies on reformulation of food and drinks to reduce free sugars and energy intake. In its report 'Feeding young children aged 1 to 5 years', SACN made the recommendation for

government to monitor intakes of low or no calorie sweeteners in children aged 1 to 5 years.

2.3 Expert-led round tables and future research on UPF

The Government Office for Science has published summaries of 2 expert roundtables on this topic held in November 2023 in a science advice note on ultra-processed foods. The first discussed the evidence base for plausible biological mechanisms for health impacts of UPF, and outstanding research priorities in this area. The second (chaired by SACN Chair Professor Ian Young) discussed epidemiology and clinical trials in relation to health impacts of UPF.

The following comments were particularly relevant.

The 2023 SACN statement (SACN, 2023a) considered lower quality (for example, cross sectional) evidence as well as higher quality evidence (prospective epidemiological studies and clinical trials). However, given the increasing number of studies in the field, it was suggested that future reports should include higher quality evidence only.

Working with the existing NOVA system and developing subcategories within category 4, based on nutritional composition in addition to processing, was considered a better alternative when compared to developing a new system at present.

The workshops considered the evidence gaps and research recommendations identified by SACN and the summaries outlined priority areas for further research including:

- hypothesis driven epidemiological studies, based on plausible mechanisms and exposures which are likely to be physiologically relevant
- substitution analysis acknowledging that UPFs replace other types of foods consumed within a dietary pattern
- controlled feeding studies with no variation between study participants' food intake
- exploring cumulative and interacting components of the diet such as additives and that consideration should be given to grouping additives and aspects of processing by potential mechanisms of action, for example, eating rate, palatability, appetite and digestion
- the challenges and limitations of designing trials to capture 'real-world' food behaviour

The summaries also outlined research and development considerations to enable research, including:

- greater transparency concerning the amounts (rather than just presence) of additives
- reframing research into UPFs as conferring both positive and negative effects
- bringing networks of labs and/or industries together to share and convene research on complex systems such as the gastrointestinal tract

SACN have noted that:

- following the roundtables, the Office for Health Improvement and Disparities is engaging with UK funders of research to identify priority areas to improve the evidence on this topic, including the NIHR which has begun to commission various research in this area
- the new contract for the NDNS rolling programme provides an opportunity to review the dietary data collection tool to achieve better estimates of exposure to processed foods

2.4 International recommendations on food processing

As discussed in SACN's 2023 position statement (SACN,2023a), several countries refer to food processing in their national dietary guidelines, including Belgium, Brazil, Brunei Darussalam, Ecuador, Israel, Kenya, Maldives, Malta, New Zealand, Peru and Uruguay.

The Nordic Nutrition Recommendations 2023 (NNR2023) report includes a section on UPF and states that:

> "Despite the observed association between ultra-processed food and health outcomes, the NNR2023 Committee decided not to formulate any specific recommendations on ultra-processed foods. NNR2023 includes several recommendations related to specific processing of foods. The NNR committee's view is that the categorization of foods as ultra-processed foods does not add to the already existing food classifications and recommendations in NNR2023."

The report notes that this is in line with guidelines from the USA, Canada and most European countries.

> "More data are needed on the mechanisms for the observed health effects of ultra-processed foods, and the various types and degrees of processing. More data are also needed to define whether the NOVA classification of ultra-processed foods add value compared to the conventional food

> categorizations used in the NNR2023 [food based dietary guidelines] FBDGs."

NNR2023 recommends:

> "minimal intake of … processed foods containing high amounts of added fats, salt and sugar."

NNR2023 also recommends:

> "overall, we recommend a predominantly plant-based diet rich in vegetables, fruits, berries, pulses, potatoes and whole grains, ample amounts of fish and nuts, moderate intake of low fat dairy products, limited intake of red meat and poultry."

It is also stated that:

> "processed food products provide a high proportion of the total fat, sugar, and salt intake. A reduced intake can be achieved by choosing varieties containing lower amounts, or by choosing more whole foods instead of processed foods."

The NNR2023 report includes:

"a number of recommendations related to food processing … such as:

- Breastfeeding should be preferred compared to infant formulas
- Consumption of [sugar sweetened beverages] SSB and energy drinks should be limited
- Whole grain cereal products should preferentially be used instead of refined cereal products
- Fruit and vegetable products with added sugar should be limited
- Intake of deep-fried potatoes and potato products with added fat and salt should be limited
- High intake of fruit juices should be avoided
- Intake of processed red and white meat (poultry) should be limited
- Milk and dairy products with high amounts of saturated fat should be limited

- Some vegetable oils should be preferred over butter and butter-mixes, hard margarine and tropical oils.
- Sweets, confectioneries and other sugary foods should be limited
- Advice on selecting more whole foods instead of processed foods for environmental reasons
- A dietary pattern with limited amounts of added total fat, saturated fat, salt and sugar is recommended
- In addition to these [food based dietary guidelines] FBDGs, several [dietary reference values] DRVs also have high relevance for food processing, including limitation of trans fatty acids, saturated fatty acids, salt and added sugar."

In May 2024 the Indian Council of Medical Research published Dietary Guidelines for Indians including to "minimise the consumption of high fat, sugar, salt (HFSS) and UPF".

In December 2024 the Scientific Report of the 2025 US Dietary Guidelines Advisory Committee was published. The committee concluded that dietary patterns consumed by children, adolescents, adults and older adults with "higher amounts of food classified as ultra-processed food are associated with greater adiposity (fat mass, waist circumference, BMI) and greater risk of obesity and/or overweight." Based on evidence graded as limited. The committee stated this "body of evidence was difficult to assess, largely because of the lack of clear definition of ultra-processed foods".

3. Evidence updates

Consideration of the evidence was in line with the SACN Framework (for more information, see the SACN webpage). Given the dominance of NOVA within the literature, this rapid update did not include an update of the evidence on existing classifications of processed foods. Only studies using the NOVA classification system were included in this evidence update.

3.1 Update on National Diet and Nutrition Survey evidence

SACN's 2023 position statement (SACN, 2023a) considered evidence applying the NOVA food processing classification system to NDNS data sets.

The position statement identified a range of limitations in applying NOVA to the NDNS. For example, the current NDNS data set does not distinguish between "mass-produced" or "artisanal" foods, nor does it distinguish between manufactured and homemade foods for

all food groups. The current NDNS data set also lacks information on food processing methods or ingredients such as sweeteners and other additives.

In the 2023 SACN position statement, 12 studies were identified which applied the NOVA classification to dietary consumption data collected through the various NDNS data sets published from 2008 to 2019. Ten of the 12 studies estimated the contribution of UPF to total dietary energy intake which varied by age group. The lowest contribution of UPF (51%) was reported in adults aged over 19 years whereas the highest contribution of UPF (68%) was reported in adolescents aged 12 to 18 years.

For this update, a further 5 studies were identified through Google Scholar alerts between 15 June 2023 and 02 May 2024. Of these, 4 publications (Watanabe and others, 2024; Sandall and others, 2023; Chavez-Ugalde and others, 2023; Dicken and others, 2023) did not meet the inclusion criteria for this rapid update. The reasons are outlined in annex 1.

Dicken and others (2024) was the only study identified in this rapid update that applied the NOVA classification to NDNS data. It was highlighted as a pre-print in the 2023 SACN position statement.

The study considered the nutrient content of foods and drinks in the NDNS Intake24 database, front of package labelling (FOPL) criteria and the NOVA classification, to understand whether UPFs are covered by dietary recommendations for foods high in fat, salt and sugar. The study found partial overlap between the UPF classification and food and drink items with a high content of saturated fat, salt and sugars available in the UK.

The study reported that UPFs tended to have an “unhealthier” nutritional profile according to the FOPL - with greater energy, fat, saturated fat, total sugar and salt content than minimally processed foods (MPFs).

The authors noted that not all UPFs were “unhealthy” (author defined) according to FOPL.

Authors noted that there was agreement among authors regarding the classification of foods into NOVA groups in this study although a “small number of items could have been coded into more than one NOVA group”.

3.2 Update on processed food and health outcomes evidence

In the 2023 SACN position statement on processed foods and health, data were extracted from 10 SRs that evaluated associations between processed food consumption and health outcomes Most SRs reported that increased consumption of processed food (specifically UPF) was associated with an increased risk of the adverse health outcomes evaluated. However, the SRs, included data solely from observational studies, mainly prospective cohort studies (PCS) and several of the SRs identified did not disaggregate prospective

and cross-sectional data. There was inconsistent adjustment for covariables as well as an inconsistency between SRs regarding the main covariables included.

In light of the wealth of new evidence published in this area since the position statement and reflecting on comments from the expert led roundtables held in autumn 2023 (see above), this evidence update focuses on higher quality evidence.

3.2.1 Methods

Eligibility criteria and literature searches

For the updated search, the UK Health Security Agency's Knowledge and Library Services (KLS) conducted online database searches to identify the following study designs, examining the relationship between 2 or more levels of food processing (as defined by NOVA) and health outcomes:

- umbrella reviews (URs) (SRs of SRs), and SRs with or without meta-analyses (MAs) (see eligibility criteria annex 2, table 4a)
- PCS that include subgroup analysis or substitution analysis (see eligibility criteria annex 2, table 4b)
- RCTs (see eligibility criteria annex 2, table 4c)

In line with the SACN Framework for the Evaluation of Evidence, SACN would usually consider primarily evidence provided by SRs and MAs of RCTs and PCS . In the SACN 2023 position statement (SACN, 2023a), given the nature of the evidence base on this topic at that time, SACN agreed that data from SRs should be extracted if they included RCTs and/or PCS, or mixed study designs if data from RCTs or PCS formed equal to or more than 70% of the total participant weighting.

In this updated evidence review, only SRs which provided separate analysis on PCS and/or RCT data were included. URs were also included in this updated review, however these included all types of observational evidence including cross-sectional studies. Individual PCS with subgroup or substitution analysis were also included.

In addition, eligibility criteria included papers published in English, in peer-reviewed scientific or medical journals. No geographical restrictions were applied. Papers were considered eligible only if:

- they evaluated predominantly healthy populations
- they evaluated one or more health outcomes

- they evaluated at least 2 levels of food processing (for example, unprocessed food compared with processed food or high intakes of UPF versus low intakes of UPF)

- “processed food” was clearly defined by a classification system

The bibliographic databases Embase, Medline (via Ovid) and PubMed were searched on 4 March 2024 using the terms outlined in annex 3. Searches to identify:

- SRs were conducted from 12 January 2023 (date of the previous search)

- RCTs were conducted from 2019 (when Hall and others (2019) was published)

- URs and PCS were conducted from 2015 (as they had not been searched for in the previous searches to identify evidence included in the SACN position statement and only papers published from 2015 onwards were included to ensure that searches captured the updated version of the NOVA classification system (Monteiro and others, 2016))

A brief search was conducted using PubMed on 4 October in 2024 to ensure no pivotal RCTs had been published since March 2024.

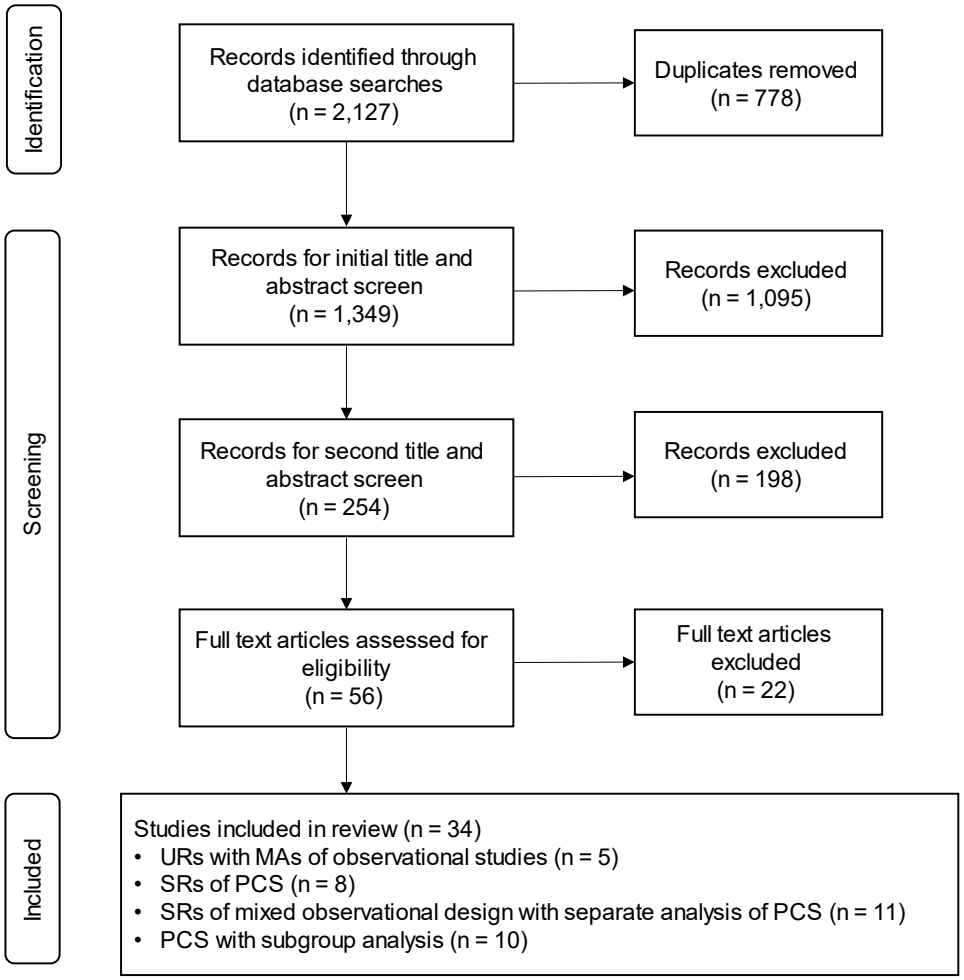
Registered trials

The USA government trial registry website ClinicalTrials.gov was searched on 27 August 2024 to identify ongoing and completed RCTs and PCS which may be of relevance to the body of evidence on food processing and associated health outcomes. The search terms were “ultra processed food” and “UPF”. Eligibility criteria with respect to the population, exposure and outcome (see annex 2, tables 4b and 4c) were applied.

Each clinical study is given a unique identification code when registering at ClinicalTrials.gov (which has an ‘NCT number’ format). We have used these codes to identify studies from ClinicalTrials.gov in this review.

Selection of studies

Figure 1: flow diagram showing the number of studies meeting the inclusion criteria for the update review of available evidence on associations between processed food consumption and health outcomes



The PRISMA flow diagram in Figure 1 shows the number of articles at each stage of the review process.

KLS conducted the online database searches identifying 2,127 references. After removing 778 duplicates, they screened the remaining 1,349 references for initial title and abstract, excluding 1,095 records.

The remaining 254 references were then rescreened for eligibility based on their title and abstract. Titles and abstracts were screened independently by 2 reviewers for eligibility, with 26 papers (10%) screened in duplicate with 93% agreement. Title and abstract screening resulted in the exclusion of a further 198 references.

The remaining 56 references were screened by full text. Five full text papers (10%) were screened in duplicate, with 100% agreement. Full text screening resulted in the exclusion of a further 22 references, with the final inclusion of 34 papers.

The rapid update identified for inclusion:

- 5 URs with MAs of observational studies
- 8 SRs of PCS
- 11 SRs of mixed observational design with separate analysis of PCS
- 10 individual PCS with subgroup analysis

No new RCTs were identified through the search.

Presentation of the evidence

For this rapid update, description of PCS which provide information on subgroup analysis were prioritised. For the URs and SRs, links and a brief summary (including aim, number of studies, exposure, association and outcomes) have been provided alongside some comparison to the results of the original SACN position statement (SACN, 2023a). Given the rapid nature of this update, detailed extraction tables have not been provided.

The quality of the evidence presented in this update has not been formally assessed.

3.2.2 Results

In comparison to the SACN position statement (SACN, 2023a) a greater number of SRs were identified that assessed only PCS or included mixed design with a separate analysis of PCS. In the 2023 position statement, of the 20 SRs that met the scoping review inclusion criteria, only 10 were fully extracted as they included either only PCS, RCTs or included mixed observational study designs with equal to or more than 70% of the total

participant weighting from PCS or RCT evidence. This compares to 8 SRs of PCS only and 11 SRs of mixed observational design with a separate analysis of PCS evidence identified in this rapid update.

No URs were identified in the position statement, whereas 5 were identified in this rapid update. This suggests an increasing volume of publications relevant to processed food and health in parallel with heightened interest in this topic. It also suggests that authors of SRs may be choosing to prioritise inclusion and separate analysis of PCS over studies of mixed observational design.

Consistent with findings from the 2023 position statement, most URs and SRs of PCS reported that increased consumption of UPF was associated with increased risks of a range of adverse health outcomes. Within the timeline for this rapid update it has not been possible to assess the quality of these SRs, the degree of adjustment for covariables and the cross-over in study inclusion. There is a risk of double counting as the SRs and PCS included in the SACN 2023 position statement are also likely to have been included in the URs and SRs listed below. No assessment of this has been carried out.

In this rapid update, primary PCS with subgroup analysis have also been included. Subgroup analysis categorises UPF into distinct food groups, providing analysis between categories and health outcomes.

3.2.3 Results of umbrella reviews

The 5 URs identified included all observational study types including cross-sectional. Links to the reviews and a brief summary are provided. Detailed information has not been extracted (as noted in above).

The 5 URs assessed the impact of UPF consumption on a wide range of health outcomes and found associations between increased UPF consumption and increased risk of the following health outcomes:

- cancer (1 UR), colon cancer (1 UR)
- respiratory (1 UR), cardiovascular (2 URs), gastrointestinal (1 UR)
- overweight and obesity (3 URs), type 2 diabetes (3URs), metabolic disease (3 URs), hypertension (4 URs) and mortality (3 URs)
- mental disorders (2 URs), depression, anxiety (1 UR)
- non-alcoholic fatty liver disease (NAFLD) (1 UR)
- Crohn’s disease (1 UR)

- low high-density lipoprotein (HDL) cholesterol, hypertriglyceridemia (1 UR)
- sleep duration (in adolescents), asthma and wheezing (both in adolescents) (1 UR)

One UR found associations between higher UPF consumption and higher intakes of energy, total fat, saturated and trans fatty acids, and lower intakes of protein, fibre, and some vitamins and minerals.

One UR reported no associations or very imprecise estimates between consumption of UPF and heart disease mortality, cancer mortality, breast cancer, prostate cancer, pancreatic cancer, chronic lymphocytic leukaemia, central nervous system tumours, ulcerative colitis, NAFLD, and hyperglycaemia.

The URs are briefly described below. Authors own grading of the certainty of the evidence included in the URs has been provided where reported:

Barbaresko and others (2024) is an UR of 16 SRs with MAs which considered the relationship between UPF consumption and human health in all age groups. Significant associations were found when higher intake of UPF was compared to lower intake of UPF for increased risk of all-cause mortality, cardiovascular disease incidence and mortality, type 2 diabetes incidence, colon cancer, Crohn's disease, low HDL cholesterol, hypertriglyceridemia, depression, metabolic syndrome, hypertension, overweight, obesity and abdominal obesity, mental disorders (in adults and also in adolescents), anxiety, sleep duration (in adolescents), asthma and wheezing (both in adolescents). Higher UPF consumption was also associated with higher intakes of energy, total fat, saturated and trans fatty acids, and lower intakes of protein, fibre, and some vitamins and minerals. No associations, or very imprecise estimates were found for heart disease mortality, cancer mortality, breast cancer, prostate cancer, pancreatic cancer, chronic lymphocytic leukaemia, central nervous system tumours, ulcerative colitis, NAFLD, and hyperglycaemia. The review assessed certainty using the GRADE framework. The certainty of the evidence was graded very low for the majority of associations.

Lane and others (2024) is an UR of 14 MAs with 45 unique pooled analyses, including identification of 13 dose response and 32 non-dose response associations. Associations were found between increased UPF and increased risk of 32 health outcomes including mortality, cancer, mental, respiratory, cardiovascular, gastrointestinal and metabolic health outcomes. The review assessed certainty using the GRADE framework. Most of the evidence was of low or very low certainty.

Lv and others (2024) is an UR of 6 SRs with 13 MAs of observational studies which considered the relationship between high versus low UPF consumption and metabolic disease risk. Three of the included MAs were assessed by the authors as "highly suggestive evidence". Among these MAs, high versus low UPF consumption was

associated with an increased risk of obesity and type 2 diabetes. Two MAs found significant associations between high versus low UPF consumption and risk of NAFLD. One MA found an association between high versus low UPF consumption and risk of hypertension. The review assessed certainty using the GRADE framework. The majority of the evidence was of very low certainty.

Wang and others (2024a) is an UR of 7 SRs with MAs which reported that high versus low UPF consumption was associated with greater risk of hypertension. The review assessed certainty using the GRADE framework and the certainty of the pooled evidence was "critically low".

Wang and others (2024b) is an UR of 14 SRs with MAs which reported that high versus low UPF consumption was associated with a greater risk of obesity, diabetes, hypertension and mortality.

3.2.4 Results of systematic reviews of randomised controlled trials and prospective cohort studies

The rapid update search identified 8 SRs of PCS. No SRs of RCTs were identified. As noted previously, links and a brief summary of these SRs are provided. Detailed information has not been extracted.

The 8 SRs of PCS assessed the impact of UPF consumption on a wide range of health outcomes and found associations between higher consumption of UPF and increased risk of the following health outcomes:

- overweight and obesity (3 SRs)
- HDL, total and low-density lipoprotein (LDL) cholesterol, triacylglycerols (1 SR) hypertriglyceridemia, low HDL cholesterol (1 SR) dyslipidaemia (1 SR)
- hypertension (3 SRs)
- diabetes (2 SRs)
- chronic kidney disease (CKD) (1 SR)
- cardio-cerebrovascular disease (1 SR), cardiovascular events and all-cause mortality (1 SR)

The SRs of PCS are as follows:

Claudino and others (2023) is an SR of 5 PCS which considered the relationship between UPF consumption and Alzheimer's disease. Four of the included 5 studies found an

association between the consumption of UPF and an increased risk of developing of Alzheimer's disease.

Frias and others (2023) is an SR of 9 PCS which considered the relationship between UPF consumption with both metabolic syndrome components and body fat in children and adolescents. Of the 9 papers, 2 reported an association between high consumption of UPF and higher total cholesterol levels; one reported an association with LDL cholesterol, one with triacylglycerols, one with diastolic blood pressure, 3 with BMI, 2 with waist circumference, and 2 with body fat.

Guo and others (2023) is an SR and MA of 39 PCS considering the relationship between UPF consumption and risk of cardio-cerebrovascular disease. A significant association was found between higher UPF consumption and increased risk of cardio-cerebrovascular disease.

Mambrini and others (2023) is an SR of 17 PCS which considered the relationship between UPF consumption and incidence of obesity and cardiometabolic risk factors in adults. Eight of the 17 PCS evaluated the incidence of general and abdominal obesity, one the incidence of impaired fasting blood glucose, 4 the incidence of diabetes, 2 the incidence of dyslipidaemia, and one the incidence of metabolic syndrome. An association between increased UPF consumption and increased risk of general and abdominal obesity, hypertension, diabetes, and dyslipidaemia was found.

Narula and others (2023) is an SR and MA of 5 PCS which considers the relationship between UPF consumption and risk of inflammatory bowel disease. High UPF consumption was associated with increased risk of Crohn's disease but not ulcerative colitis.

Vitale and others (2024) is an SR and MA of 25 PCS which considers the relationship between UPF consumption and major cardiovascular disease risk factors which included diabetes, hypertension, dyslipidaemia, and obesity. Associations were found for higher UPF consumption and increased risk of diabetes, hypertension, hypertriglyceridemia, low HDL cholesterol concentration and obesity.

Xiao and others (2024) is an SR and MA of 4 PCS which considers the relationship between UPF consumption and the risk of incident CKD. There was a significant association between high UPF consumption and increased risk of incident CKD.

Yuan and others (2023) is an MA of 11 PCS which considers the relationship between UPF consumption and cardiovascular events and all-cause mortality. There were significant associations between high UPF consumption and increased risk of cardiovascular events and all-cause mortality.

The rapid update search identified 11 SRs of studies with mixed observational design with a separate analysis by PCS. As noted previously, links and a brief summary of these SRs are provided. Detailed information has not been extracted.

The 11 SRs of observational studies with separate analysis by PCS assessed the impact of UPF consumption on a wide range of health outcomes and found associations between higher consumption of UPF and increased risk of the following health outcomes:

- risk of obesity (1 SR)
- dental caries (1 SR)
- dementia (1 SR)
- cancer (1 SR), colorectal cancer (1 SR)
- risk of depression (2 SRs)

No associations were found for the following health outcomes:

- metabolic syndrome (1 SR)
- breast cancer (1 SR)
- anxiety (1 SR)
- NAFLD (1 SR)
- adult inflammatory bowel disease - Crohn’s disease and ulcerative colitis (1 SR)

The SRs of studies with mixed observational design with a separate analysis of PCS are as follows:

Babaei and others (2023) is an SR with dose-response MA of 24 observational studies (11 PCS and 13 case-control studies) which considered the relationship between UPF consumption and adult inflammatory bowel disease risk in all age groups. A significant association was found between UPF consumption and Crohn’s disease but not ulcerative colitis, although there was no association when only PCS were analysed.

Cascaes and others (2023) is an SR with MA of observational studies (7 PCS, 1 non-RCT, 1 case-control study and 18 cross-sectional studies) which considered the relationship between consumption of UPF foods or food groups and dental caries (measured as decayed, filled and missing surfaces or teeth indexes) in children and adolescents.

Significant associations were found between higher UPF consumption and risk of dental caries when only PCS and non-RCTs were included in the analysis.

Henney and others (2023) is an SR and MA of 9 observational studies (3 PCS, 3 cross-sectional and 3 case control studies) which considered the relationship between UPF consumption and NAFLD. Both moderate and high consumption of UPF were associated with increased risk of NAFLD. Sensitivity analyses showed no significant association when only PCS were included in the analysis.

Henney and others (2024) is an SR and MA of 10 observational studies (8 cohort, 1 case-control study and 1 cross-sectional study) which considered the relationship between UPF consumption and dementia. An association was found between higher UPF consumption and increased risk of dementia, which remained when only PCS were included in the analysis.

Isaksen and others (2023) is an SR and MA of 11 observational studies (3 PCS and 8 case-control studies) which considered the relationship between UPF consumption and cancer risk. When pooling all the different types of cancer and only including PCS in the analysis, UPF consumption was associated with an increased risk of cancer.

Mazloomi and others (2022) is an SR and MA of 26 observational studies (10 PCS, 14 cross sectional and 2 case-control studies) which considered the relationship between UPF consumption and mental ill health in adults. When only including PCS in the analysis, an association was found between higher UPF consumption and greater risk of depression. There was no association with anxiety, so this was not analysed by study type.

Moradi and others (2021) is an SR and MA of 12 observational studies (3 PCS and 9 cross-sectional studies) which considered the relationship between UPF consumption and risk of obesity in adults. An association was found between higher UPF consumption and increased risk of obesity when only including PCS in the analysis.

Shu and others (2023a) is an SR and MA of 6 observational studies (3 PCS and 3 case-control studies) which considered the relationship between UPF consumption and risk of breast cancer. When only including PCS in the analysis, no association was found between UPF consumption and risk of breast cancer.

Shu and others (2023b) is an SR and MA of 7 observational studies (3 PCS and 4 case-control studies) which considered the relationship between UPF consumption and risk of colorectal cancer. When only including PCS in the analysis, there was a significant association between higher UPF consumption and risk of colorectal cancer.

Shu and others (2023c) is an SR and MA of 9 observational studies (3 PCS and 6 cross-sectional studies) which considered the relationship between UPF consumption and risk of metabolic syndrome. When only including PCS in the analysis, no association was found between UPF consumption and risk of metabolic syndrome.

Tian and others (2023) is an SR of 28 observational studies (6 PCS, 21 cross-sectional studies and 1 case-control study) which considered the relationship between UPF consumption and risk of depression. Four of the 6 included PCS found an association between higher UPF consumption and increased risk of depression.

3.2.5 Results of prospective cohort studies subgroup analyses

The rapid update search identified 10 individual PCS for inclusion, which conducted subgroup analyses of prospective cohort data where UPFs were analysed by food category. Five of the 10 studies considered the USA Nurses' Health Study, the Nurses' Health Study II and/or Health Professional Follow Up study. More detail is provided for the PCS subgroup evidence compared with the URs and SRs as these types of studies were not reviewed within the 2023 position statement. Detailed information for PCS has not been extracted, except the covariables adjusted for in multivariable or multivariate analyses. Table 2a and table 2b lists the adjustments made by the PCS and shows inconsistency particularly in relation to adjustments for measures of socioeconomic status, BMI and energy intake.

The 10 PCS assessed associations between UPF and the following health outcomes, results varied by subgroup of UPF assessed:

- type 2 diabetes (2 PCS)
- cardiometabolic multimorbidity (1 PCS)
- Crohn's disease (1 PCS), ulcerative colitis (1 PCS)
- total mortality (1 PCS), cancer mortality (1 PCS), cardiovascular mortality (1 PCS), other mortality (1 PCS), respiratory mortality (1 PCS), neurodegenerative mortality (1 PCS)
- hypertension (1 PCS)
- incident frailty (1 PCS)
- colorectal cancer (1 PCS)
- gout (1 PCS)

- colorectal cancer precursor polyps (conventional adenomas and serrated lesions) (1 PCS)

Canhada and others (2023)
Canhada and others (2023) is a PCS (the ELSA-Brazil Cohort) which considered the association between higher versus lower UPF consumption (as defined by NOVA) and health outcomes. Investigators considered specific subgroups of UPF and incident type 2 diabetes in Brazilian adults. The analysis included 10,202 participants during 8.2 (plus or minus 0.7) years of follow-up.

The PCS included subgroup analysis of 9 categories of UPF, which were:

- ready-packaged bread
- baked and fried snacks
- non-dairy sweet snacks and desserts
- spreads
- yoghurt and dairy sweets
- processed meats
- ready-to-eat and heat mixed dishes
- sweetened beverages
- distilled alcoholic beverages

Consumption of UPF was expressed continuously for 50g per day and a one standard deviation (SD) difference. Relative risks were calculated for both crude and adjusted models (adjustments were age, sex, centre or location, race and skin colour, income, school achievement, family history of diabetes, smoking, physical activity and alcohol).

Higher consumption of processed meats and sweetened beverages increased the adjusted risk of type 2 diabetes in both analyses. For processed meat, the relative risk for a one SD (21g) difference was 1.08 (95% confidence interval (CI) 1.04 to 1.13). For sweetened beverages, the relative risk for a one SD (230ml) difference was 1.14 (95% CI 1.10 to 1.18). Greater consumption of yogurt and dairy sweets decreased risk in both analyses, with a 61g per day difference having an adjusted relative risk of 0.94 (95% CI 0.89 to 0.98). A significant association was found for distilled alcohol beverages for both analyses in the crude model, but not in the adjusted model. No statistically significant associations were found for consumption of ready-packaged bread, baked and fried

snacks, non-dairy sweet snacks and desserts, spreads, or ready-to-eat and heat mixed dishes.

The authors reported the following study limitations:

> "First, our food frequency questionnaire was not specifically designed for the NOVA classification. Although these questionnaires are commonly used to assess nutritional intake in epidemiological studies, our lack of specificity in identifying UPFs may lead to an underestimation of the size of the associations reported. Furthermore, it reflects only partially the large amount of UPFs available today. However, the quantity of ultra-processed foods consumed in this cohort is in line with that of a nationwide representative survey assessed with detailed food registries.
>
> "Second, our approximately eight-year follow-up may be too short to evaluate the total contribution of UPFs to the development of a chronic condition such as diabetes.
>
> "Third, although we performed multiple adjustments for possible confounders in statistical analyses, we cannot rule out residual or unmeasured confounding, particularly since some potential mediators may also be potential confounders.
>
> "Fourth, since our cohort started at age 35, we cannot extrapolate our findings to younger groups. Finally, although, following the design of most cohort studies, we did not randomly draw our sample from the Brazilian adult population, it captures Brazil's racial, social, and regional diversity."

Chen and others (2023)

Chen and others (2023) is an analysis of 3 PCS (the Nurses' Health Study, the Nurses' Health Study II and the Health Professional Follow Up study) which considered the relationship between higher versus lower UPF consumption (as defined by NOVA) and risk of type 2 diabetes. The analysis included 198,636 participants during 5,187,678 person-years of follow (mean not provided).

The PCS included subgroup analysis of 9 categories of UPF, which were:

- ultra-processed breads and cereals (subdivided into ultra-processed cereals, ultra-processed dark breads and whole-grain breads and ultra-processed refined breads)
- sauces, spreads and condiments
- packaged savoury snacks

- artificially and sugar-sweetened beverages (subdivided into artificially sweetened beverages and sugar-sweetened beverages)
- animal-based products
- ready-to-eat and heat mixed dishes
- yoghurt and dairy-based desserts
- confectioneries
- other UPFs

Consumption of UPF was measured as servings per day. Hazard ratios (HR) were calculated using a model adjusted for age, race and/or ethnicity (white or other), family history of diabetes, history of hypercholesterolemia, history of hypertension, baseline BMI, smoking status, physical activity, oral contraceptive use, postmenopausal hormone use, physical examination in the past 2 years, neighbourhood income, total energy, and total alcohol consumption.

Among subgroups, statistically significant associations with increased risk of type 2 diabetes were identified for refined breads (HR 1.05; 95% CI 1.02 to 1.07); sauces, spreads, and condiments (HR 1.05; 95% CI 1.03 to 1.06); artificially sweetened (HR 1.09; 95% CI 1.08 to 1.11); and sugar-sweetened beverages (HR 1.15; 95% CI 1.12 to 1.17); animal-based products (HR 1.44; 95% CI 1.38 to 1.51); and ready-to-eat and ready-to-heat mixed dishes (HR 1.05; 95% CI 1.02 to 1.07).

Significant associations of reduced risk of type 2 diabetes were identified for ultra-processed cereals (HR 0.78; 95% CI 0.75 to 0.82); dark and whole-grain breads (HR 0.96; 95% CI 0.94 to 0.98); packaged sweet and savoury snacks (HR 0.91; 95% CI 0.87 to 0.94); fruit-based products (HR 0.82; 95% CI 0.77 to 0.86); and yogurt and dairy-based desserts (HR 0.91; 95% CI 0.88 to 0.95). No association was identified for confectioneries.

The authors reported the following study limitations:

> “There are several limitations that are worth discussing. First, in the [nurses and health professional surveys], dietary assessment was conducted using [food frequency questionnaires] FFQs, which inevitably include measurement errors. However, the use of the cumulative average of repeated measured dietary data reduced random measurement errors caused by within-person variation.
>
> “Furthermore, because FFQs do not cover the full spectrum of foods consumed, including UPFs, potential misclassification of some food items as

ultra-processed may have introduced confounding, especially in UPF subgroup analyses. Indeed, given the lack of an assessment of validity of the FFQs used for assessing UPF intake in the three U.S. cohorts, it is acknowledged that the NOVA classification relies, at least partly, on assumptions and generalizations about food categories. A thorough validation study remains needed. Still, previous studies suggested that it was acceptable to use FFQs to identify and rank intake of UPFs.

"Also, the cohorts included primarily health professionals of Caucasian origin, which limits generalizability of our findings to other ethnic or socioeconomic groups. The latter also applies to results from the MA, because participants from all included cohorts had such profiles.

"Finally, although all cohorts in the MAs had been controlled for a series of potential confounders, we cannot rule out the possibility of residual confounding."

Cordova and others (2023)

Cordova and others (2023) is a PCS (using the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort) which considered the relationship between higher versus lower UPF consumption (as defined by NOVA) and the risk of multimorbidity defined as the co-occurrence of at least 2 chronic diseases in an individual among first cancer at any site, cardiovascular disease, and type 2 diabetes. The analysis included 266,666 participants during a median of 11.2 years of follow up.

The PCS included subgroup analysis of 9 categories of UPF, which were:

- ultra-processed breads and cereals
- sauces, spreads and condiments
- sweets and desserts
- savoury snacks
- plant-based alternatives
- animal-based products
- ready to eat and heat mixed dishes
- artificially and sugar sweetened beverages
- other UPFs

UPF consumption was measured as per one SD increment, estimated to be around 260g per day food or drinks (excluding alcoholic drinks). Hazard ratios were calculated using a model adjusted for total energy intake, baseline alcohol intake, height, smoking status, physical activity, education, plausibility of dietary energy reporting (under-reporter, acceptable, over-reporter), and modified relative Mediterranean Diet Score, post-menopause hormone therapy, and menopausal status in women.

Associations with increased risk of cancer-cardiometabolic multimorbidity were identified for animal-based products (HR 1.09; 95% CI 1.05 to 1.12), and artificially and sugar-sweetened beverages (HR 1.09; 95% CI 1.06 to 1.12). No significant associations were identified for ultra-processed breads and cereals, spread, sauces and condiments, sweets and desserts, savoury snacks, plant-based alternatives, ready to eat and heat mixed dishes, or other UPFs.

The authors reported the following study limitations:

> “First, the Nova classification was implemented on dietary data captured more than 20 years ago at recruitment of participants into EPIC. However, three scenarios were considered when classifying food items and ingredients according to Nova to evaluate the impact of possible exposure misclassification, and results were similar. In addition, Nova misclassification might have occurred due to missing food processing information in the FFQs and assumptions were necessary while classifying the foods. However, data collected via 24-h dietary recalls in subsample of individuals in all countries were used to inform assumptions and minimize misclassification.
>
> “Second, we collected diet and other lifestyle exposure data at recruitment, and potential changes in modifiable behaviours during follow-up, especially after the diagnosis of [non-communicable diseases] NCDs, were not possible to account for in our study. However, our results suggest that pre-diagnostic lifestyle habits are associated with the risk of NCDs and multimorbidity, assuming that exposure characteristics before the onset of a disease can influence subsequent health outcomes. Therefore, possible improvements in health behaviours after the diagnosis of a first NCD would most likely have resulted in an underestimation of the observed relative risks.
>
> “Third, we were unable to account for treatment information after the first NCD. Among persons with type 2 diabetes, a common first-line medication is metformin, which is linked to a decreased risk of cardiovascular events and possibly some cancers. In contrast, cancer therapy can increase the risk of cardiac diseases and diabetes. Nevertheless, if treatment alone does not influence diet habits, the observed result should not be affected by the lack of treatment information. Furthermore, we cannot exclude the possibility that

unmeasured confounding, such as family history of (premature) cancer and cardiometabolic disease, could have affected the results. Lastly, our findings should be generalized with caution because study participants may not always be representative of the general population and only seven of the 10 countries in the EPIC study were included."

Fang and others (2024)

Fang and others (2024) is an analysis of 2 PCS (the Nurses' Health Study and the Health Professionals Follow-up Study) examining the association of higher versus lower UPF consumption (as defined by NOVA) with all-cause mortality and cause specific mortality. The analysis included 74,563 women and 39,501 men during a median of 34 and 31 years of follow-up, respectively. To note these 2 cohorts were also assessed by Chen and others (2023).

The PCS included subgroup analysis of 9 categories of UPF, which were:

- ultra-processed breads and breakfast foods
- fats, condiments and sauces
- packaged sweet snacks and desserts
- sugar and artificially sweetened beverages
- ready to eat and heat mixed dishes
- meat, poultry and seafood based ready-to-eat products
- packaged savoury snacks
- dairy-based desserts
- other

UPF consumption was measured as cumulative averages (quarters). Results from Cox proportional hazards model were stratified by age (months), questionnaire cycle (2-year interval) and cohort, and adjusted for total energy intake, race, marital status, physical activity, BMI, smoking status and pack years, alcohol consumption, physical examination performed for screening purposes, family history of diabetes mellitus, myocardial infarction, or cancer; for women, also menopausal status and hormone use.

The study found an increased risk of total mortality with higher consumption of ultra-processed breads and breakfast foods (HR 1.03; 95% CI 1.01 to 1.06), sugar and artificially sweetened beverages (HR 1.09; 95% CI 1.06 to 1.12), ready-to-eat and heat

mixed dishes (HR 1.03; 95% CI 1.00 to 1.06), meat, poultry and seafood based ready-to-eat products (HR 1.13; 95% CI 1.10 to 1.16), dairy based desserts (HR 1.06; 95% CI 1.03 to 1.08) and other UPF (HR 1.04; 95% CI 1.03 to 1.06). No associations were found between total mortality and the other food groups.

It found an increased risk of cancer mortality with higher UPF consumption and meat, poultry and seafood based ready-to-eat products (HR 1.06; 95% CI 1.01 to 1.11) and other UPF (HR 1.03; 95% CI 1.01 to 1.07). It found a reduced risk of cancer mortality with higher consumption of packaged sweet snacks and desserts (HR 0.94; 95% CI 0.89 to 0.98). No associations were found between cancer mortality and the other food groups.

The study found an increased risk of cardiovascular mortality with higher consumption of sugar and artificially sweetened beverages (HR 1.13; 95% CI 1.06 to 1.19), meat, poultry and seafood based ready-to-eat products (HR 1.14; 95% CI 1.09 to 1.21) and other UPF (HR 1.07, 95% CI 1.04 to 1.09). It found a reduced risk of cardiovascular mortality with higher consumption of packaged sweet snacks and desserts (HR 0.93; 95% CI 0.88 to 0.98). No associations were found between cancer mortality and the other food groups.

It found an increased risk of other mortality with higher consumption of packaged sweet snacks and desserts (HR 1.04; 95% CI 1.00 to 1.08), sugar and artificially sweetened beverages (HR 1.14; 95% CI 1.09 to 1.18), ready-to-eat and heat mixed dishes (HR 1.09; 95% CI 1.04 to 1.14), meat, poultry and seafood based ready-to-eat products (HR 1.17; 95% CI 1.13 to 1.21), dairy based desserts (HR 1.13; 95% CI 1.09 to 1.17) and other UPF (HR 1.04; 95% CI 1.02 to 1.06). No associations were found between other mortality and the other food groups.

It found an increased risk of respiratory mortality with higher consumption of ultra-processed breads and breakfast foods (HR 1.11; 95% CI 1.01 to 1.21), ready-to-eat and heat mixed dishes (HR 1.17; 95% CI 1.05 to 1.29), meat, poultry and seafood based ready-to-eat products (HR 1.42; 95% CI 1.30 to 1.56) and dairy based desserts (HR 1.14; 95% CI 1.04 to 1.24). No associations were found between respiratory mortality and the other food groups.

It found increased risk of neurodegenerative mortality with higher consumption of packaged sweet snacks and desserts (HR 1.18; 95% CI 1.09 to 1.26), sugar and artificially sweetened beverages (HR 1.14, 95% CI 1.05 to 1.23), packaged savoury snacks (HR 1.07; 95% CI 1.01 to 1.15) and dairy based desserts (HR 1.41; 95% CI 1.32 to 1.50).

The authors reported the following study limitations:

> “Firstly, we cannot rule out unmeasured and residual confounding due to the nature of the observational study. Secondly, our participants are health professionals and predominantly non-Hispanic white, limiting the

generalizability of our findings. Thirdly, as the food frequency questionnaires collected intake of only a limited number of pre-defined items representing the primary source of energy and nutrients in the US population and were not designed to classify foods by processing level, they may not capture the full spectrum of ultra-processed foods. Although the food frequency questionnaires used in our cohorts have been validated for foods and nutrients, they were not specifically validated for ultra-processed foods.

"Moreover, we classified ultra-processed foods by using the same algorithm throughout follow-up that did not account for changes in the grade of food processing over time. These factors may have introduced nondifferential misclassification, likely biasing our results towards the null."

Hang and others (2023)

Hang and others (2023) is an analysis of three PCS (the Nurses' Health Study, the Nurses' Health Study II and the Health Professional Follow Up study) examining the impact of higher versus lower UPF consumption (as defined by NOVA) on the risk of colorectal cancer (CRC) precursor polyps (conventional adenomas and serrated lesions). The analysis included 142,052 participants and 18 to 20 years of follow up. To note these 3 cohorts were also assessed by Chen and others (2023).

The PCS included subgroup analysis of 8 categories of UPF (NOVA group 4), which were:

- ultra-processed breads and breakfast foods
- fats, condiments and sauces
- packaged sweet snacks and desserts
- beverages
- ready to eat and heat mixed dishes
- meat, poultry and seafood based ready-to-eat products
- packaged savoury snacks
- yoghurt and dairy-based desserts

UPF consumption was estimated as (energy adjusted) servings per day. Odds ratios (OR) were calculated using a multivariate model adjusted for age, race, cohort, time period of endoscopy, number of prior endoscopies, and time in years since the most recent endoscopy (continuous), family history of colorectal cancer, total alcohol intake, physical

activity, smoking status, regular aspirin use, and menopausal status and hormone use in women. The analysis was also mutually adjusted for the individual subgroups.

Associations between higher versus lower UPF consumption (quintile 1 versus quintile 5) and increased risk of high-risk polyps were observed for meat, poultry and seafood-based ready-to-eat products (OR 1.20; 95% CI 1.09 to 1.32), fat, condiment, and sauces (OR 1.18; 95% CI 1.08 to 1.30), packaged sweet snacks and desserts (OR 1.13; 95% CI 1.03 to 1.24), and ultra-processed breads and breakfast food (OR 1.13; 95% CI 1.03 to 1.24).

The authors reported the following study limitations:

> "First, as in any observational study, unmeasured confounders cannot be ruled out despite robust adjustment for established risk factors.
>
> "Second, because colorectal polyps are usually asymptomatic and cannot be diagnosed until an endoscopic exam, this study was restricted to participants who had undergone endoscopy. Although this raises concerns about selection bias, the similar consumption of UPF intake in this study and in the overall cohorts indicates little influence of selection bias on our findings.
>
> "Third, the FFQs are unable to cover the full spectrum of UPF consumption. Also, the FFQs used in the cohorts were not specifically designed to classify foods according to the extent of processing; however, given the prospective design, non-differential misclassification of the exposure likely could have biased our results toward the null.
>
> "Finally, the study participants were all health professionals and predominantly White, which may limit the generalizability of our findings. However, the homogeneity of our study population reduces the likelihood of uncontrolled confounding. There are no prior data indicating that UPFs have different carcinogenic effects according to race and ethnicity. Nevertheless, we acknowledge the need for further studies in more diverse study populations."

Lo and others (2022)

Lo and others (2022) is an analysis of 3 PCS (the Nurses' Health Study, the Nurses' Health Study II and the Health Professional Follow Up study) examining the impact of higher versus lower UPF (as defined by NOVA) on risk of Crohn's disease (CD) and ulcerative colitis. The analysis included 203,516 women and 41,596 men, contributing to 5,468,444 person-years of follow-up (mean or details of study length not provided). To note these 3 cohorts were also assessed by Chen and others (2023) and Hang and others (2022).

The PCS included subgroup analysis of 9 categories of UPF, which were:

- ultra-processed breads and breakfast foods
- frozen or shelf-stable ready-to-eat and heat meals
- packaged sweet snacks and desserts
- sauces, cheeses, spreads, and gravies
- dairy-based desserts
- beverages
- meat and meat-substitute-based products
- packaged savoury snacks
- other

UPF consumption was modelled as one standard deviation increase in the percentage of total energy intake from that subgroup. Results from Multivariable Cox proportional hazards models were stratified by age, cohort, and questionnaire cycle with adjustment for race and/or ethnicity, family history of inflammatory bowel disease (IBD), smoking status, BMI, physical activity, total energy intake, Alternate Healthy Eating Index-2010, regular non-steroidal anti-inflammatory drugs (NSAID) use, oral contraceptives, and menopausal hormone therapy.

Association between higher versus lower consumption and increased CD risk were identified for ultra-processed breads and breakfast foods (HR 1.18; 95% CI 1.07 to 1.29), frozen or shelf-stable ready-to-eat and heat meals (HR 1.11; 95% CI 1.01 to 1.22) and sauces, cheeses, spreads, and gravies (HR: 1.14; 95% CI 1.02 to 1.27). There was no association between other individual UPF subgroups and CD risk, or between any individual UPF subgroup and ulcerative colitis risk.

The authors reported the following limitations:

> “First, the cohort overall skewed older compared with other population-based cohorts due to our long-term follow-up. Although extrapolating our findings to those with younger-onset diseases should be done with caution, thus far there has not been any convincing demonstration of a differential impact of environmental factors on younger- and older-onset IBD. In addition, we observed similar findings in a sensitivity analysis restricting to participants under 60 years of age.

> “Second, there may be measurement error in UPF consumption due to potential secular changes in the degree of processing of foods, variation across brands, and incomplete labelling over the study period. Such changes in additive content may explain the more modest effect of cumulative average UPF intake when compared with simple updated intake. We acknowledge that the lack of a comprehensive nutritional database to capture such trends limited the ability to incorporate these important factors into the analysis.
>
> “Third, we observed a lower percentage of total energy intake from UPFs among our study participants. This could be due to participants being health professionals and consuming an overall healthier diet, our relatively conservative approach for classifying UPFs, or the limited resolution in assessing the degree of food processing through [semi-quantitative FFQs] SFFQs.
>
> “Fourth, as in any observational study, the potential for unmeasured confounders must be acknowledged despite robust adjustment for established environmental risk factors. We lacked information on certain risk factors such as history of antibiotic use and exposure to air pollution. However, we did not expect these to be differential between strata of UPF intake. We also did not have information on socioeconomic status. Nonetheless, the cohorts consisted mostly of white health professionals. Although this and the use of common instruments established the high degree of internal validity within the study, with the emergence of IBD globally, it is important to replicate our findings in racially and ethnically diverse cohorts.”

Monge and others (2021)

Monge and others (2021) is a PCS (using the Mexican Teachers’ Cohort) examining the association between ultra-processed beverages and processed meat consumption (as defined by NOVA) and hypertension in women. The analysis included 64,934 women with a median follow up of 2.2 years (inter quartile range) 1.8 to 4.4).

The PCS included subgroup analysis of 9 categories of UPF, which were:

- dairy products
- added fats
- sugary products
- sugar-sweetened beverages

- alcoholic beverages
- processed meats
- cereals
- salty snacks
- fast food

UPF consumption was analysed as percentage of total daily energy intake. Poisson regression models were used to estimate multivariable-adjusted incidence rate ratios (IRR) adjusted for age, indigenous, internet access, insurance (private, social, other), family history of hypertension, menopausal status, smoking, physical activity, energy intake and multivitamin intake.

Liquid UPF (sugar sweetened beverages and alcoholic beverages) (IRR 1.32; 95 % CI 1.10 to 1.65) and processed meats (IRR 1.17; 95 % CI 1.01 to 1.36) consumption were statistically significantly associated with increased hypertension. Significant association with hypertension was not identified for the other UPF categories.

The authors reported the following limitations:

> "Our FFQ was not designed to assess UPF items, thus leading to potential misclassification of UPF (non-differential to hypertension status) and may have decreased the variability of the exposure.
>
> "Another limitation is that hypertension diagnosis was self-reported, but it has been used in other cohort studies and has been shown to be a valid indicator in Hispanics. Self-reported hypertension had a moderately high positive predictive value (79%), so while measurement error is possible, this error is likely non-differential since the exposure was assessed before the outcome.
>
> "The short follow-up time might also have diminished our ability to detect an association. It is also possible that UPF intake has a long-term effect which was not captured in 2·2 years of follow-up. Loss to follow-up was about 15%, which may result in selection bias. Yet, when comparing baseline characteristics of the women included in our analysis versus lost to follow-up, we did not observe important differences. We also included a table comparing the characteristics of women who had a valid FFQ [versus] an invalid FFQ (about 27,000). Participants with a valid FFQ were more likely to have family history of hypertension and also had higher multivitamin intake; otherwise, they did not appear healthier.

> “Due to the observational nature of our data, residual confounding cannot be ruled out. All participants were teachers, while it may increase internal validity, it may decrease generalisability to other populations if potential effect modifiers of this association differ by population or age distribution. Yet, we do not believe there are biological differences among female teachers and other women that would make us believe that the effect of UPF consumption on hypertension is different.”

Sandoval-Insausti and others (2020)

Sandoval-Insausti and others (2020) is a PCS (using the Seniors-ENRICA (Study on Nutrition and Cardiovascular risk factors in Spain) cohort) examining the association between higher versus lower UPF consumption (as defined by NOVA) and incident frailty in older adults. The analysis included 1,882 participants with a mean follow-up of 3.5 years.

The study included subgroup analysis of 12 categories of UPF (NOVA group 4), which were:

- breads
- cookies
- cakes and pastries
- breakfast cereals
- yoghurts and fermented milks
- dairy desserts
- meat and meat products
- jams and confectionery
- sauces and dressings
- pre-cooked dishes
- soft drinks
- non-alcoholic beverages

UPF consumption was expressed at percentage of energy intake. Odds ratios were calculated using a model adjusted for sex, age, level of education, marital status, tobacco

consumption, former-drinker status, chronic respiratory disease, coronary disease, stroke, osteoarthritis and/or arthritis, cancer, depression, and number of medications used.

Among subgroups of UPF, higher consumption of non-alcoholic beverages (OR 2.26; 95% CI 1.35 to 3.77), yoghurts and fermented milks (OR 1.78; 95% CI 1.11 to 2.85), and cakes and pastries (OR 1.75; 95% CI 1.04 to 2.96) were significantly associated with increased incident frailty in older adults. No association was found for the other UPF subgroups.

The authors reported the following study limitations:

> "Some limitations should be noted. First, as in most nutritional epidemiology studies, a certain recall bias cannot be ruled out because diet was self-reported. Second, although there was agreement among authors about NOVA classification of our participants' diet, certain ultra-processed food misclassification cannot be ruled out. Third, the number of frailty cases was relatively small, but we still found quite strong associations. Fourth, the low number of consumers in some ultra-processed food groups (such as breakfast cereals, dairy desserts, and soft drinks) may not allow to achieve statistical significance in those groups. Finally, although we adjusted for the potential confounders, some residual confounding may persist."

Wang and others (2022)

Wang and others (2022) is an analysis of 3 PCS (the Nurses' Health Study, the Nurses' Health Study II and the Health Professional Follow Up study) examining the association between higher versus lower UPF consumption (as defined by NOVA) and colorectal cancer. A total of 366,155 participants were included with 24 to 28 years of follow up (mean not provided). To note these 3 cohorts were also assessed by Chen and others (2023), Hang and others (2022) and Lo and others (2022).

The study included subgroup analysis of 8 categories of UPFs, which were:

- meat, poultry and seafood-based ready-to-eat products
- ultra-processed bread and breakfast food
- packaged sweet snacks and desserts
- fats, condiment, and sauces
- sugar or artificially sweetened beverages
- yoghurt and dairy-based desserts

- ready-to-eat and heat mixed dishes
- packaged savoury snacks
- other ultra-processed foods

The percentage of total energy consumed from UPF was calculated for each participant. Cox proportional hazards regression models were used, stratified simultaneously by age (in years) and calendar year of return of questionnaire (every 2 years since the baseline questionnaire) and adjusted for race, family history of cancer, history of endoscopy, physical activity, smoking status and pack years of smoking, total alcohol intake, total caloric intake, and regular aspirin use and menopausal status and post-menopausal hormone use in women.

Among subgroups of UPF, higher consumption of meat, poultry and seafood based ready-to-eat products (HR 1.44; 95% CI 1.20 to 1.73) and sugar sweetened beverages (HR 1.21; 95% CI 1.01 to 1.44) among men and ready-to-eat and heat mixed dishes among women (HR 1.17; 95% CI 1.01 to 1.36) was associated with increased risk of colorectal cancer. Yogurt and dairy based desserts were associated with lower risk of colorectal cancer among women (HR 0.83; 95% CI 0.71 to 0.97).

The authors reported the following study limitations:

> "Firstly, owing to the study's observational nature, residual confounding due to unmeasured confounders and measurement error of covariates cannot be ruled out.
>
> "Secondly, as FFQs collect intake from only a limited number of pre-defined items representing the primary source of energy and nutrients in the study population, they cannot cover the full spectrum of ultra-processed foods consumed. Additionally, FFQs used in the three cohorts were not designed to classify food intake by levels of processing, which may lead to non-differential misclassification of the exposure. For example, nine food items lacked sufficient details in the resource documents to support their classification. We have adopted a more conservative approach assuming a lower level of processing in the primary analyses. Our sensitivity analyses using alternative classification did not materially alter the results.
>
> "Thirdly, our cohort participants are US health professionals and predominantly non-Hispanic white, limiting the generalizability of our study findings. The homogeneity of our study population may have led to reduced variability in dietary intake. Stronger associations might be observed in populations with a more heterogeneous diet. Nevertheless, the associations

between many risk factors and colorectal cancer risk identified in our cohorts are highly concordant with those reported in World Cancer Research Fund/American Institute of Cancer Research systematic reviews."

Zhang and others (2024)

Zhang and others (2024) is a PCS (using the UK Biobank cohort) examining the relationship between higher versus lower UPF consumption (as defined by NOVA), genetic predisposition, and the risk of gout. The analysis included 181,559 individuals with a total of 1,648,167 person-years of follow-up (range in years and mean not provided).

The PCS included subgroup analysis of 7 categories of UPF, which were:

- beverages
- fruits and vegetables
- meat, fish, and eggs
- bread and breakfast cereals
- snacks and pastries
- sauces
- vegetarian alternatives

UPF consumption (g per day) was expressed per one SD increment in each UPF food group. Cox proportional hazards models were adjusted for age, sex, BMI, education levels, Townsend deprivation index, physical activity, total energy intake, smoking status, drinking status, family history of diseases (hypertension, cardiovascular disease, and diabetes), healthy diet score and medical history of hypertension, diabetes, kidney disease, cancer, and cardiovascular disease.

Of the UPF categories, beverages (HR 1.16; 95% CI 1.10 to 1.22), fruits and vegetables (HR 1.07; 95% CI 1.00 to 1.15), meat, fish, and eggs (HR 1.15; 95% CI 1.09 to 1.21) and snacks and pastries (HR 1.07; 95% CI 1.01 to 1.13) were associated with a higher gout risk.

Substitution analysis reported that replacing 20% of the weight of UPF in daily intake with an equal amount of unprocessed or minimally processed food resulted in a 13% lower risk of gout (HR 0.87; 95% CI 0.79 to 0.95).

The authors reported the following study limitations:

"First, as an observational study, there is a possibility of selection bias and residual confounding; although we adjusted for multiple confounders, it might still be confounded by other factors.

"Second, measurement error might be present, because the diet factors were measured using a questionnaire.

"Third, the misclassification of UPF may be a concern, because the indication of food processing information was limited in the UK Biobank.

"Fourth, given the observational nature of this study, a causal relationship between UPF consumption, genetic predisposition, and gout cannot be inferred.

"Fifth, incident gout was diagnosed using participants' hospital inpatient records, which may have led to an underestimation of gout incidence. Thus, participants with gout who were untreated or treated in primary care could have been misclassified. However, it is unlikely that undiagnosed or unreported gout cases would be specific to UPF intake at baseline, which implies that the outcome of misclassification would have less bias effect on the derived relative estimate (that is HR).

"Sixth, we note that UPF consumption was based on dietary intake over the past 24h, which means that variability in eating habits over time may not have been fully captured.

"Finally, it is unknown whether our results may be applied to other demographic or ethnic groups, because the participants in our study were middle-aged and older individuals of European ancestry."

3.2.6 Assessment of PCS subgroup analysis

There was substantial heterogeneity between UPF categories within the PCS with subgroup analysis, making it difficult to compare analyses. For example, one PCS included the category "meat and meat-substitute-based alternatives", which would likely have included both meat products and meat-free alternatives. Another study included "plant-based alternatives" which would likely only have included meat-free alternatives and not meat products, and possibly with the addition of other plant-based alternatives such as plant-based drinks. Consequently, it was not appropriate to tabulate categories from different PCS together.

Tables 1a to 1i attempt to collate results for similar categories to enable some comparison between studies. These results can be summarised as follows.

Subgroups including meat and animal products were found to be associated with increased risk of multiple health outcomes, whereas studies found no association between vegetarian alternative products and health outcomes.

Sweetened beverages subgroups were found to be associated with increased risk of multiple health outcomes.

One PCS found bread and/or cereals subgroups to be associated with lowered risk of type 2 diabetes, and another found an association with increased risk of Crohn's disease. Other PCS found no association between breads and/or cereals and a range of health outcomes. One PCS found that when further subdivided, the subgroup "other ultra-processed refined breads" increased the risk of type 2 diabetes.

Results for the subgroups: savoury snacks, sauces and/or spreads and/or condiments and/or fats, ready to eat foods, "other UPF" and alcoholic beverages were mixed. Some studies found adverse health associations whereas others did not.

Results for the subgroups: dairy products or dairy based dessert or sweets and sweet, sugary snacks or desserts were found to have a mix of no, reduced or increased risk of adverse health outcomes.

Tables 1a to 1i: results of PCS subgroup analyses of different categories of UPF (NOVA group 4) split by a range of health outcomes

The tables below present the data in a way that allows for some comparison between studies, however the variation in methods of categorisation between studies does not fully allow for this. Categories including ‘alcoholic beverages’ have not been included in the tables due to restricted space. Canhada and others (2023) found no association between consumption of alcoholic beverages and type 2 diabetes; Mong and others (2021) found an increased association between consumption and hypertension. All of the findings are author reported.

Abbreviations: UPF: ultra processed food; NSA: no statistically significant association; IR: increased risk; DR: decreased risk; NA: not assessed.

Table 1a: type 2 diabetes

Study	Bread and cereals	Savoury snacks	Sweet snacks	Dairy	Animal-based	Plant-based	Ready meals	Condiments	Other	Sweet drinks
Canhada and others (2023)	Ready-packaged bread	Baked and fried snacks	Non-dairy sweet snacks and desserts	Yoghurt and dairy sweets	Processed meats	NA	Ready-to-eat and heat mixed dishes	Spreads	NA	Sweetened beverages
Finding	NSA	NSA	NSA	DR	IR	NA	NSA	NSA	NA	IR
Chen and others (2023)	Ultra-processed breads and cereals	Packaged savoury snacks	Packaged sweet snacks and desserts	Yoghurt and dairy based desserts	Animal-based products	NA	Ready-to-eat mixed dishes	Sauces, spreads and condiments	Other processed foods	Artificially and sugar-sweetened beverages
Finding	DR	DR	DR	DR	IR	NA	IR	IR	IR	IR

Table 1b: cancer-cardio-metabolic multi-morbidity

Study	Bread and cereals	Savoury snacks	Sweet snacks	Dairy	Animal-based	Plant-based	Ready meals	Condiments	Other	Sweet drinks
Cordova and others (2023)	Ultra-processed breads and cereals	Savoury snacks	Sweets and desserts	NA	Animal-based products	Plant-based alternatives	Ready to eat and heat mixed dishes	Sauces, spreads and condiments	Other UPF	Artificially and sugar sweetened beverage
Finding	NSA	NSA	NSA	NA	IR	NSA	NSA	NSA	NSA	IR

Table 1c: mortality (cancer, cardiovascular, respiratory, neurodegenerative, total and other)

Study	Bread and cereals	Savoury snacks	Sweet snacks	Dairy	Animal-based	Plant-based	Ready meals	Condiments	Other	Sweet drinks
Fang and others (2024)	Ultra-processed breads and breakfast foods	Packaged savoury snacks	Packaged sweet snacks and desserts	Dairy based desserts	Meat, poultry and seafood based ready-to-eat products	NA	Ready-to-eat and heat mixed dishes	Fats, condiments and sauces	Other	Sugar and artificially sweetened beverages

Study	Bread and cereals	Savoury snacks	Sweet snacks	Dairy	Animal-based	Plant-based	Ready meals	Condiments	Other	Sweet drinks
Finding: total mortality	IR	NSA	NSA	IR	IR	NA	IR	NSA	IR	IR
Finding: cancer mortality	NSA	NSA	DR	NSA	IR	NA	NSA	NSA	IR	NSA
Finding: cardiovascular mortality	NSA	NSA	DR	NSA	IR	NA	NSA	NSA	IR	IR
Finding: other mortality	NSA	NSA	IR	IR	IR	NA	IR	NSA	IR	IR
Finding: respiratory mortality	IR	NSA	NSA	IR	IR	NA	IR	NSA	NSA	NSA
Finding: neurodegenerative mortality	NSA	IR	IR	IR	NSA	NA	NSA	NSA	NSA	IR

Table 1d: high-risk polyps

Study	Bread and cereals	Savoury snacks	Sweet snacks	Dairy	Animal-based	Plant-based	Ready meals	Condiments	Other	Sweet drinks
Hang and others (2023)	Ultra-processed breads and breakfast foods	Packaged savoury snacks	Packaged sweet snacks and desserts	Yoghurt and dairy based desserts	Meat, poultry and seafood based ready-to-eat products	NA	Ready-to-eat and heat mixed dishes	Fat, condiments and sauces	NA	Beverages
Finding	IR	NSA	IR	NSA	IR	NA	NSA	IR	NA	NSA

Table 1e: Crohn's disease and ulcerative colitis

Study	Bread and cereals	Savoury snacks	Sweet snacks	Dairy	Animal-based	Plant-based	Ready meals	Condiments	Other	Sweet drinks
Lo and others (2022)	Ultra-processed breads and breakfast foods	Packaged savoury snacks	Packaged sweet snacks and desserts	Dairy-based desserts	Meat and meat-substitute-based products	NA	Frozen or shelf-stable ready-to-eat and heat meals	Sauces, cheeses, spreads, and gravies	Other UPF	Beverages
Finding: Crohn's disease	IR	NSA	NSA	NSA	NSA	NA	IR	IR	NSA	NSA
Finding: ulcerative colitis	NSA	NSA	NSA	NSA	NSA	NA	NSA	NSA	NSA	NSA

Table 1f: hypertension

Study	Bread and cereals	Savoury snacks	Sweet snacks	Dairy	Animal-based	Plant-based	Ready meals	Condiments	Other	Sweet drinks
Monge and others (2021)	Cereals (including bread)	Salty snacks	Sugary products	Dairy products	Processed meats	NA	Fast food	Added fats	NA	Sugar sweetened beverages
Finding	NSA	NSA	NSA	NSA	IR	NA	NSA	NSA	NA	IR

Table 1g: incident frailty

Study	Bread and cereals	Savoury snacks	Sweet snacks	Dairy	Animal-based	Plant-based	Ready meals	Condiments	Other	Sweet drinks
Sandoval-Insausti and others (2020)	Breads and breakfast cereals	NA	Cookies; cakes and pastries	Yoghurts and fermented desserts; dairy desserts	Meat and meat product	NA	Pre-cooked dishes	Sauces and dressing	Jams and confectionaries	Soft drinks; other non-alcoholic beverages
Finding	NSA	NA	NSA; IR	IR; NSA	NSA	NA	NSA	NSA	NSA	NSA; IR

Table 1h: colorectal cancer

Study	Bread and cereals	Savoury snacks	Sweet snacks	Dairy	Animal-based	Plant-based	Ready meals	Condiments	Other	Sweet drinks
Wang and others (2022)	Ultra-processed bread and breakfast food	Packaged savoury snacks	Packaged sweet snacks and desserts	Yoghurt and dairy-based desserts	Meat, poultry and seafood-based ready-to-eat products	NA	Ready-to-eat and heat mixed dishes	Fat, condiment, and sauces	Other UPF	Sugar- or artificially sweetened beverages
Finding	NSA	NSA	NSA	DR in women	IR in men	NA	IR in women	NSA	NSA	IR in men

Table 1i: gout

Study	Bread and cereals	Savoury snacks	Sweet snacks	Dairy	Animal-based	Plant-based	Ready meals	Condiments	Other	Sweet drinks
Zhang and others (2024)	Breads and breakfast cereals	(Sweet and savoury) snacks and pastries	See savoury snacks	NA	Meat, fish and eggs	Vegetarian alternatives	NA	Sauces	UPF fruit and veg	Beverages (sugar and artificially sweetened)
Finding	NSA	IR	See savoury snacks	NA	IR	NSA	NA	NSA	IR	IR

Table 2a: summary table of adjustments made by PCS studies (to note that ethnicity is often stated as 'race' and 'white/non white')

Participant characteristic	Canhada and others (2023)	Chen and others (2023)	Cordova and others (2023)	Fang and others (2024)	Hang and others (2023)
Age	Yes	Yes	No	Yes	Yes
Sex	Yes	No	No	No	No
Ethnicity	Yes	Yes	No	Yes	Yes
Income or socioeconomic status	Yes	Yes	No	No	No
Smoking	Yes	Yes	Yes	Yes	Yes
Family history of illness	Yes	Yes	No	Yes	Yes

Participant characteristic	Canhada and others (2023)	Chen and others (2023)	Cordova and others (2023)	Fang and others (2024)	Hang and others (2023)
Education	Yes	No	Yes	No	No
Physical activity	Yes	Yes	Yes	Yes	Yes
Alcohol	Yes	Yes	Yes	Yes	Yes
BMI	No	Yes	No	Yes	No
Total energy	No	Yes	Yes	Yes	No
Nutritional	No	No	Yes	No	No
Other	None	Menopausal status	Menopausal status	Menopausal status	Menopausal status
Other	None	Hormone use	Hormone use	Hormone use	Hormone use
Other	None	Recent physical	Height	Recent physical for screening	Aspirin use
Other	None	History of hypercholesterolemia	Plausibility of energy intake	Marital status	Timing of endoscopy
Other	None	History of hypertension	None	None	None

Table 2b: summary table of adjustments made by PCS studies (to note that ethnicity is often stated as 'race' and 'white/non-white')

Participant characteristic	Lo and others (2022)	Monge and others (2021)	Sandoval-Insausti and others (2020)	Wang and others (2022)	Zhang and others (2024)
Age	Yes	Yes	Yes	Yes	Yes

Participant characteristic	Lo and others (2022)	Monge and others (2021)	Sandoval-Insausti and others (2020)	Wang and others (2022)	Zhang and others (2024)
Sex	No	No	Yes	No	Yes
Ethnicity	Yes	Yes	No	Yes	No
Income or socioeconomic status	No	No	No	No	Yes
Smoking	Yes	Yes	Yes	Yes	Yes
Family history of illness	Yes	Yes	No	Yes	Yes
Education	No	No	Yes	No	Yes
Physical activity	Yes	Yes	No	Yes	Yes
Alcohol	No	No	Yes	Yes	Yes
BMI	Yes	No	No	No	Yes
Total energy	Yes	Yes	No	Yes	Yes
Nutritional	Yes	No	No	No	Yes
Other	Hormone use	Menopausal status	Marital status	Hormone use	Medical history of hypertension
Other	NSAID	Multivitamin use	Number of medications used	Menopausal status	Medical history of kidney disease
Other	None	Internet access	Chronic respiratory disease	Year of questionnaire return	Medical history of diabetes
Other	None	Insurance	Coronary disease	History of endoscopy	Medical history of cancer

Participant characteristic	Lo and others (2022)	Monge and others (2021)	Sandoval-Insausti and others (2020)	Wang and others (2022)	Zhang and others (2024)
Other	None	None	Stroke	Aspirin use	Medical history of cardiovascular disease
Other	None	None	Osteoarthritis and/or arthritis	None	None
Other	None	None	Depression	None	None
Other	None	None	Cancer	None	None

Nine PCS assessed a variation of a meat and animal products subgroup. Two PCS assessed “processed meats”. One of which found that increased consumption of processed meats was associated with an increased risk of type 2 diabetes, and the other found an increased risk of hypertension. Two PCS assessed “animal-based products” and found that increased consumption was associated with an increased risk of type 2 diabetes in one study, and cancer-cardiometabolic multimorbidity in the other study. Three PCS assessed meat, poultry and seafood-based ready to eat products. One found an association with increased risk of colorectal cancer in men only, one found an association with increased risk of total mortality, cancer mortality, cardiovascular mortality, other mortality and, respiratory mortality and one found an association with high-risk polyps. One PCS assessed “meat, fish and eggs” and found an increased risk of gout. One PCS assessed “meat and meat products” and found no association with incident frailty.

Three PCS assessed a version of vegetarian alternative products, either as “meat and meat-substitute-based alternatives”, “plant-based alternatives” or “vegetarian alternatives”. One PCS assessed “meat and meat-substitute-based alternatives” and found no association with Crohn’s disease or ulcerative colitis. One PCS assessed “plant-based alternatives” and found no association with cancer-cardiometabolic multimorbidity. One PCS assessed “vegetarian alternatives” and found no association with gout.

Ten PCS assessed variations of a beverages subgroup of UPF. Three PCS assessed “artificially and sugar sweetened beverages” and found an association between increased consumption and increased risk of type 2 diabetes in one study, cancer-cardiometabolic multimorbidity in another study, and total, cardiovascular, other and neurodegenerative mortality, but not cancer mortality or respiratory mortality, in the other study. One PCS assessed “sugar sweetened beverages” and found an association with increased risk of hypertension. One PCS assessed “sweetened beverages” (not stated whether sweetened with sugars and/or NSS) and found an association with increased risk of type 2 diabetes. One PCS assessed “beverages” (including those sweetened with sugars and NSS) and found an association with increased risk of gout. One PCS assessed “beverages” and found no association with Crohn’s disease or ulcerative colitis. Another PCS assessed “beverages” (not stated whether sweetened with sugars and/or NSS) and found no association with high-risk polyps. Another PCS assessed “non-alcoholic beverages” and found an association with increased risk of incident frailty. One PCS further subdivided the category of “artificially and sugar-sweetened beverages” and found a slightly increased risk associated with sugar-sweetened beverage consumption and type 2 diabetes compared to “artificially sweetened beverages”.

Ten PCS assessed bread and/or cereals as a subgroup. One PCS found that “ultra-processed breads and cereals” consumption was associated with a lower risk of type 2 diabetes. One PCS found that “ultra-processed breads and breakfast foods” was associated with a higher risk of Crohn’s disease. One PCS found that “ultra-processed breads and breakfast foods” was associated with a higher risk of total and respiratory

mortality but not cancer, cardiovascular, other or respiratory mortality. One PCS found that “ultra-processed breads and breakfast foods” was associated with a greater risk of high-risk polyps. All other PCS found no association between breads and/or cereals and a range of health outcomes. One PCS further subdivided the category of “ultra-processed breads and cereals” and found that the overall category lowered the risk of type 2 diabetes (as did “ultra processed cereals” and “ultra-processed dark breads and whole-grain breads”. Conversely, “other ultra-processed refined breads” increased the risk of type 2 diabetes.

Eight PCS assessed a version of savoury snacks as a sub-category, either as “baked and fried snacks”, “packaged savoury snacks”, “savoury snacks” or “salty snacks”. One PCS found that consumption of “packaged savoury snacks” was associated with decreased risk of type 2 diabetes. Another found that “packaged savoury snacks” was associated with increased risk of neurodegenerative mortality, but not total mortality, cancer or cardiovascular mortality, other or respiratory mortality. Six of the 8 PCS found no associations with a range of health outcomes.

Ten PCS assessed categories of sauces and/or spreads and/or condiments and/or fats. Two PCS assessed “sauces, spreads and condiments”, with one reporting an association between increased consumption and increased risk of type 2 diabetes and the other reporting no association with cancer-cardiometabolic multimorbidity. Two PCS assessed “sauces” and found no association with type 2 diabetes in one study, or gout in the other study. One PCS assessed “sauces, cheeses, spreads and gravies” and found an association with increased risk of Crohn’s disease, but no association with ulcerative colitis. Three PCS assessed “fat, condiments and sauces”, with one reporting an association with increased risk of high-risk polyps and the others finding no association with a range of health outcomes. One PCS assessed “added fats” and found no association with hypertension. One PCS assessed “sauces and dressings” and found no association with incident frailty.

Eight PCS assessed dairy products or dairy based dessert and sweets. Three PCS assessed “yoghurt and dairy based desserts”. One reported a reduced risk of type 2 diabetes associated with consumption of this category. Another PCS reported a reduced risk of colorectal cancer among women. The third found no association with high-risk polyps. Two PCS assessed “dairy based desserts”, one found increased risk of total mortality, other mortality, respiratory mortality and neurodegenerative but not cancer mortality or cardiovascular mortality whereas the other found no association with Crohn’s disease or ulcerative colitis. One PCS assessed "yoghurt and dairy based sweets” and found a reduced risk of type 2 diabetes. One PCS found no association between “dairy desserts” but did find an increased risk of incident frailty and “yoghurt and fermented desserts”.

Nine PCS assessed sweet or sugar containing snacks or desserts. Five PCS assessed “packaged sweet snacks and desserts”. One reported a decreased risk of type 2 diabetes, one reported a greater risk of high-risk polyps and one reported a lower risk of cancer and cardiovascular mortality, a higher risk in other mortality and neurodegenerative mortality, and no association with total mortality and respiratory mortality. The other PCS reported no association with a range of other health outcomes. One PCS assessed “sweets and desserts” and found no association with cancer-cardiometabolic multimorbidity. One PCS assessed “sugary products” and found no association with hypertension. One PCS assessed “non-dairy sweet snacks and desserts” and found no association with type 2 diabetes. One PCS found an association between higher consumption of “cakes and pastries” and increased risk of incident frailty, but no association between “cookies” or “jams and confectionaries” and incident frailty.

Nine PCS assessed ready-to-eat food categories. One PCS reported an increased risk of colorectal cancer in women, one PCS reported an increased risk of total mortality, other mortality and respiratory mortality but no association with cancer, cardiovascular or neurodegenerative mortality. One PCS found higher consumption of “ready to eat mixed dishes” was associated with an increased risk of type 2 diabetes, while another assessed “ready to eat and heat mixed dishes” and found no association with type 2 diabetes. One PCS assessed “frozen or shelf stable ready to eat/heat meals” and found higher consumption was associated with an increased risk of Crohn’s disease and no association with ulcerative colitis. One PCS found no association between “pre-cooked dishes” and incident frailty. One PCS assessed “fast food” consumption and found no association with hypertension. Another 2 PCS reported no association with a range of health outcomes.

Five PCS assessed consumption of “other UPF”. One reported an association between greater consumption and an increased risk of type 2 diabetes, another reported an increased risk with total cancer mortality, cardiovascular mortality and other mortality but not with respiratory mortality or neurodegenerative mortality. The others reported no association with a range of health outcomes.

Two PCS assessed alcoholic beverages. One reported an association between greater consumption and an increased risk of hypertension, and the other reported no association with type 2 diabetes.

Some PCS subcategorised UPF into categories that others did not. For example, one PCS analysed “snacks and pastries” including both sweet and savoury snacks together. Another PCS assessed UPF “fruit and vegetables”. Another PCS assessed “fast food”, and another “soft drinks”. One PCS also assessed “non-alcoholic beverages” (separately to “soft drinks”).

3.2.7 Results of randomized controlled trials

No new RCTs meeting the inclusion criteria for this review were identified in the updated search.

A small RCT (9 participants) published in September 2024, was identified after the cut-off for the search for this evidence update (Hamano and others, 2024). The study was conducted in a clinical setting and the nine participants were living with overweight or obesity. The study was a crossover design comparing the effect of one week consumption of a UPF diet with a non-UPF diet on body weight with a 2 week wash out period. During the UPF period, participants gained 1.1kg more weight (95% CI 0.2 to 2.0; P = 0.021) and consumed 813.5 kilocalories (kcal) more per day (342.4 to 1284.7; P = 0.004) compared with during the non-UPF period. Regarding the chewing frequency, the number of chews per calorie was significantly lower during the UPF period (P = 0.016). A p-value is a statistical measurement used to validate a hypothesis against observed data. The lower the p-value, the greater the statistical significance of the observed difference.

A recent SR of RCTs published in June 2024, was identified after the cut-off date for the search (Aramburu and others, 2024). The aim of this SR was to determine whether associations between higher intake of UPFs and adverse health outcomes could be confirmed in RCTs. Aramburu and others (2024) included 4 RCTs, the study by Hall and others previously identified in the 2023 SACN position statement (Hall and others 2020, as per 2019 publication, republished with a correction). The 3 further studies would not meet the eligibility criteria of this rapid update (annex 2, table 4a) as they included educational interventions or personalised nutritional counselling with recommendations to avoid or limit the consumption of UPFs.

The lack of evidence from RCTs comparing either the consumption of NOVA groups 1, 2, or 3 with UPF (NOVA group 4), or high versus low UPF consumption is reinforced by Aramburu and others 2024 and the inclusion of only 4 RCTs, 3 of which did not meet SACN's eligibility criteria.

3.3 Updated trial registry

A total of 96 ongoing or completed studies were identified from the ClinicalTrials.gov search conducted on 27 August 2024. The search terms used were "ultra processed foods" and "UPF". Fifty-two were excluded as they had been identified during the last search on 21 June 2023 for the SACN position statement. Of the remaining 44, 35 were excluded based on the PCS and RCT eligibility criteria in annex 2, tables 4b and 4c respectively. Nine studies, one PCS and 8 RCTs, remained of potential relevance. The details of these studies can be found in annex 4.

Each study set out to evaluate 2 or more levels of food processing or high versus low consumption of UPF and associated markers of health or health outcomes.

The status of one study which looked at the effect of a single ultra-processed meal on myocardial endothelial function, was noted as completed, with results currently unavailable (ClinicalTrials.gov study identifier: NCT06353009).

SACN is aware that the eligibility criteria may not have identified all ongoing trials of relevance in this area. For example, a trial that was not picked up in the search compares the effects of 2 healthy, balanced diets following the advice in the UK Eatwell Guide, but each based on a different type of food processing (NCT05627570). The diets do not seem to be matched for energy density and overall calories. Also not picked up by the search is another trial being undertaken by Wageningen University on food texture (NCT05561426).

Also of note is an additional RCT being carried out to develop further the RCT published in 2019 (Hall and others, 2019) with a focus on energy density. This was identified in the trial registry search of the 2023 SACN position statement (NCT05290064).

3.4 Other studies of interest

SACN is aware that other primary studies of interest have been published that did not meet the search criteria for this evidence update.

SACN is also aware of a number of feeding studies that have investigated food texture and eating rate:

In a 2 × 2 randomised crossover dietary intervention of 18 adults (Lasschuijt and others 2023) (previously identified in the trial registry search of the 2023 SACN position statement), 4 conditions were studied (total of 288 meals) including: hard unprocessed, hard (ultra-) processed, soft unprocessed and soft (ultra-) processed. Daily diets were offered ad libitum and were matched for energy density. Daily energy intake and food intake were lower in the hard compared to the soft conditions. Eating rate was slower in the hard compared to the soft conditions. Level of processing did not affect food intake.

In a randomised crossover study of 50 participants (Teo and others, 2022), 4 lunch meals were consumed consisting of "soft minimally processed", "hard minimally processed", "soft ultra-processed", and "hard ultra-processed" components. Meals were matched for total energy served, with some variation in meal energy density. "Hard minimally processed" and "hard ultra-processed" meals were consumed slower overall, food weight (g) and energy (kcal) consumed was reduced. Intakes were higher for "soft ultra-processed" and "soft minimally processed" meals, after correcting for meal pleasantness. The effect of texture on food weight consumed was not influenced by processing levels, but the effect of food texture on energy intake was. The least energy was consumed from the "hard

minimally processed" meal and the most from the "soft ultra-processed" meal. Energy intake was lowest when harder texture was combined with the "minimally processed" meals. To note this was not included in the SACN 2023 position statement as eating rate did not meet the inclusion criteria for outcome.

A modelling study of cross-sectional consumption data (Estell and others 2022) reported that “exclusion of UPF may result in lowered intakes of key nutrients of particular concern for at risk groups (including women of child-bearing age)”, This highlights the contribution of fortified UPF food to nutrient intake.

4. Limitations

SACN notes the limitations of this rapid update. The included studies have not been fully extracted or assessed for quality.

The inclusion cut-off date for publications was the search date 4 March 2024. Other relevant studies were included if they were identified after this cut-off date. As this is such a rapidly evolving field there are likely to be studies published since then that would meet the inclusion criteria (see annex 2) that have not been included in this evidence update.

SACN identified a range of limitations in the evidence included within the position statement on processed foods (SACN, 2023a). The limitations previously identified were also observed within this update review. These include but are not limited to:

Lack of a universally agreed definition of ultra-processed foods. The research literature is dominated by NOVA, therefore any limitations or biases of the NOVA classification may be replicated throughout the research literature. Assessment of the NOVA approach identified some concerns around practical application in the UK. In particular, the classification of some foods is discordant with nutritional and other food-based classifications.

Difficulties in applying NOVA to the NDNS. The NDNS does not currently capture all the detail required for classifying foods according to NOVA. For example, it does not include information on sweeteners or other additives, nor the method of food processing or packaging.

Uncertainties around the quality of the available evidence. This is because the available evidence was almost exclusively observational (and therefore unable to show causation) and confounding factors or covariates might not have been adequately accounted for.

Uncertainties to what extent observed associations between (ultra-) processed foods and adverse health outcomes were explained by established relationships between nutritional factors and health outcomes on which SACN had undertaken robust risk assessments.

The available literature continues to contain limited or no information on the processing or presence or amount of additives, that have led to food being classified as UPF. As such it remains unclear what independent effect they may have over and above established nutritional characteristics.

It has not been possible to undertake a full assessment of the adjustments made by authors of included studies for covariates likely to cause confounding. However, brief assessment of more recently published PCS with subgroup analysis indicates that covariates continue to be inconsistently accounted for, particularly in relation to socio-economic status, BMI, energy and nutritional intake, all of which may be related to the health outcomes considered. Adjustment for energy intake may be particularly important. UPFs are often energy dense, highly palatable and may promote higher energy intakes.

In observational studies, the principal means of assessing the impact of energy intake on observed outcomes is to statistically adjust for energy intake. If an association is present before adjustment, but absent or much reduced after adjustment, this suggests that the health effect can be explained wholly or in part by increased energy intake. Studies which only report the energy-adjusted result might mask the degree to which an association is mediated via excess energy intake.

Limitations of the URs and SRs were not assessed in detail, however the SRs in the URs included cross-sectional studies and are likely to be at risk of a range of issues previously identified by SACN (2023). Authors of PCS with subgroup analyses reported similar limitations to those identified by SACN (2023), including:

- limitations of the dietary collection methods including FFQs, for example recall bias, measurement error, the difficulty in capturing variability of the diet, as well as FFQs not being validated for applying the NOVA classification and assumptions required for classification of NOVA resulting in UPF misclassification

- the age of dietary data resulting in only a partial reflection of the current availability of UPFs

- follow up too short to evaluate the contribution of UPFs to the development of a chronic conditions

- despite multiple adjustments being made for possible confounders, residual or unmeasured confounding could not be ruled out, as well as a lack of information on important confounders including socio-economic status

- selection bias due to non-random sample and limited generalisability to the general population

- potential changes to modifiable behaviours during follow-up, especially after the diagnosis of NCDs and inability to account for treatment information after the first NCD
- method of diagnosis, for example self-reported or use of hospital patient records

Additional limitations of the PCS with subgroup analyses were identified. There was substantial heterogeneity between UPF categories making it difficult to directly compare the analyses. In addition, 5 of the 10 PCS are based on analysis of the same 2 cohorts (the Nurses' Health Study and the Health Professionals Follow-up Study), and 4 of the 5 PCS are based on the same 3 cohorts (the Nurses' Health Study, the Nurses' Health Study II and the Health Professional Follow Up study).

5. Summary and conclusions

5.1 Summary of results

Evidence identified in this rapid evidence update suggests that the NOVA classification system continues to dominate the research literature. Authors continue to refer to the challenges with reliably applying NOVA and estimating UPF consumption.

In line with discussions at the Government Office for Science expert round tables, this evidence update has focused on higher quality evidence from URs, SRs of PCS and PCS with subgroup analysis of NOVA UPF categories. Assessment of the evidence is consistent with the SACN framework.

5.1.1 Umbrella reviews and systematic reviews

The search identified:

- 5 URs
- 8 SRs of PCS only
- 11 SRs of observational studies with a separate analysis by PCS

Consistent with findings of the SACN position statement on processed foods and health (SACN, 2023a), the majority of URs and SRs of prospective cohorts consistently reported that increased consumption of UPF was associated with increased risk of a broad range of adverse health outcomes. These included, but were not limited to, overweight and obesity, type 2 diabetes, cardiovascular, cancer and mental health conditions.

5.1.2 Prospective cohort studies subgroup analysis

This rapid update has identified 10 PCS that carried out a subgroup analysis of the associations of UPF consumption with a range of health outcomes by food type to understand more about the association between UPF consumption and adverse health outcomes.

There was heterogeneity between the sub-categorisation of UPF into different food subgroups, making it difficult to directly compare results by subgroups. However, analyses suggests that UPF categories including meat and animal products and sweetened beverages are associated with an increased risk of adverse health outcomes. By contrast, other UPF categories including vegetarian meat-alternative products were found to have no association with adverse health outcomes. UPF categories of bread and/or cereals subgroups, savoury snacks; dairy products or dairy based dessert or sweets; and sweet or sugary snacks or desserts; sauces and/or spreads and/or condiments and/or fats; ready to eat foods; “other UPF” and alcoholic beverages were all found to have mixed results.

5.1.3 Other studies

One study applied NOVA to NDNS intake data, reporting that UPFs tended to have an “unhealthier” nutritional profile according to the FOPL - with greater energy, fat, saturated fat, total sugar and salt content than minimally processed foods (MPFs).

This rapid update identified only one small (n=9) RCT, which found participants gained more weight (1.1kg) on UPF diet compared to non-UPF diet. A check of a trial registry (ClinicalTrials.gov) during the drafting of this statement indicated that a number of registered trials were underway on the topic of processed foods and health, which will contribute to the evidence base on this topic, including studies considering food texture and eating rate.

5.1.4 Limitations

It has not been possible within the timeline for this evidence update to assess the quality of the identified URs, SRs and PCS with subgroup analysis. However, limitations identified in the 2023 SACN position statement remain. In particular, studies appear to inconsistently account for important covariates such as socio-economic status, BMI, energy and nutritional intake, all of which may be related to the health outcomes considered.

Authors of PCS with subgroup analyses detailed common limitations of their studies including:

- issues related to data collection methods
- lack of validation for data collection methods such as FFQ

- the age of dietary data and how relevant it is given the wide variety of UPF available today
- difficulties in reliably classifying UPF and use of the NOVA classification system
- issues with short follow up and being able to identify the contribution of UPF to risks of long term chronic diseases
- selection bias and limited generalisability of findings to the general population as well as a risk of residual confounding

5.2 Discussion

URs and SRs of PCS published since March 2023 consistently reported that increased consumption of UPF was associated with increased risks of adverse health outcomes. Observed associations are consistent with findings from the SACN position statement published in July 2023 (SACN, 2023a). SACN continues to find these observations very concerning.

Additional evidence from subgroup analyses of PCS indicates that not all UPFs may affect health in the same way, with variation by food category. The categories of UPF consistently associated with adverse health outcomes were those including meat and animal products and sweetened beverages on which SACN has already made recommendations.

As SACN found in its 2023 position statement, the available evidence remains almost exclusively observational in nature, with only one small (n=9) RCT identified and SACN identified a range of methodological issues with the available evidence. This is a very active research area. There are a number of ongoing registered trials and in addition better quality observational data and SRs are also likely to be published, which may address some of the limitations identified in the current evidence base.

A detailed assessment of the quality of studies included in this evidence update has not been carried out and it is therefore not known how well these studies adjusted for covariates likely to cause confounding. Studies appear to adjust for important covariates inconsistently, particularly for measures of socioeconomic status and BMI. Even after covariate adjustments have been made, it is likely that there remains residual confounding. Additionally, the limitations associated with assessing processed food consumption within observational data as outlined in the SACN 2023 position statement remain. Given the potential role of energy as a mechanism for the association between UPF and ill health it would be helpful to consider the health effects both with and without correction for the effects of total energy intake.

The evidence base considered contains limited or no information on the health impacts of processing or ingredients used within foods leading them to be classified as UPFs. It is therefore not possible to assess any effects these have on health separately from the established effects of the poor nutritional characteristics of UPF.

In 2025 SACN published a position statement on the WHO guideline on non-sugar sweeteners (SACN, 2025).

In previous reports SACN has already made a number of recommendations in relation to processed foods and drinks (see table 3).

Diets high in UPF are often energy dense, high in saturated fat, salt or free sugars, high in processed meat and/or low in fruit and vegetables and fibre. SACN has already concluded in previous robust risk assessments that consumption of excess energy, saturated fat, salt, free sugars and processed meat is linked to poor health outcomes, and higher consumption of fruit and vegetables, wholegrain foods and fibre reduces health risks.

SACN notes that higher consumption of foods classified as UPF is likely to be indicative of a less healthy dietary pattern in much the same way as a diet that has a higher Mediterranean diet score or Healthy Eating Index indicates a healthier dietary pattern.

Existing UK dietary advice, based on SACN recommendation, is largely consistent with international recommendations.

More recently, some countries have actively recommended a reduction in consumption or avoidance of (ultra) processed foods or recommend consuming minimally processed foods. Of note are the NNR2023, which recommend:

> “a predominantly plant-based diet rich in vegetables, fruits, berries, pulses, potatoes and whole grains, ample amounts of fish and nuts, moderate intake of low fat dairy products, limited intake of red meat and poultry, and minimal intake of processed meat, alcohol, and processed foods containing high amounts of added fats, salt and sugar.”

On food based dietary guidelines, the report states that:

> “more data are … needed on the mechanisms for the observed health effects of ultra-processed foods … and whether the NOVA classification of ultra-processed foods adds value compared to the conventional food categorizations.”

Table 3: summary of SACN recommendations in relation to processed foods

SACN report	Recommendation
Iron and health report (SACN, 2010)	Adults with relatively high intakes of red and processed meat (over 90g per day) to consider reducing their intakes to the population average for adults (about 70g per day) due to an association between red and processed meat and bowel cancer.
Carbohydrates and health report (SACN, 2015)	Sugar-sweetened drinks should be minimised given observed associations with risk of weight gain in children and dental caries and type 2 diabetes.
Carbohydrates and health report (SACN, 2015)	Updated population fibre recommendations and as such UK dietary recommendations encourage consumption of wholegrain starchy foods.
Feeding young children aged 1 to 5 years report (SACN, 2023)	Foods (including snacks) that are energy dense and high in saturated fat, salt or free sugars should be limited.
Feeding young children aged 1 to 5 years report (SACN, 2023)	Dairy products including yogurts should ideally be unsweetened.
Feeding young children aged 1 to 5 years report (SACN, 2023)	Sugar-sweetened beverages should not be given.
Feeding young children aged 1 to 5 years report (SACN, 2023)	Follow on formula and commercially manufactured foods and drinks marketed specifically for infants and young children are not needed to meet nutritional requirements for this age group.

5.3 Conclusions

Consistent associations are observed between higher consumption of UPF and adverse health outcomes. SACN continues to find the observed associations between higher consumption of (ultra-) processed foods and adverse health outcomes concerning.

There continues to be significant limitations in the evidence base. It remains unclear to what extent observed associations between (ultra-) processed foods and adverse health outcomes are explained by established relationships between nutritional factors and health outcomes on which SACN has undertaken robust risk assessments (SACN, 2003; SACN, 2010; SACN, 2011; SACN, 2015; SACN, 2019). While there remain concerns and difficulties around the commonly used NOVA classification system, further subgroup analysis of foods classified as UPF suggests there may be potential to develop

subcategories within the existing NOVA classification, based on nutritional composition in addition to processing.

SACN notes that subgroup analyses to date indicate increased risk of poor health outcomes in relation to a number of food categories including processed meat and sugar and non-sugar sweetened beverages. SACN has already made recommendations in relation to these foods (table 3). The reasons for heterogeneity in relation to findings for other subgroups remain unclear. SACN notes that while there is substantial overlap between foods that would be classified as UPF and those high in energy, saturated fat, salt and free sugars, this overlap is incomplete. Furthermore, a range of limitations continue to beset this evidence base, particularly confounding by other known risks.

SACN notes that it only has a remit in relation to risk assessment. Consumer understanding and application of the concept of UPF, and whether consumers find it more helpful in making healthier choices compared to existing dietary messaging is beyond SACN's remit. However, SACN notes that the UK's national food model, The Eatwell Guide, which is based on SACN's recommendations, already indicates that many foods classified as ultra-processed (such as crisps, biscuits, cakes, confectionery, and ice cream) are not part of a healthy, balanced diet. It also emphasises a diet based on fruit, vegetables and wholegrain or higher fibre starchy carbohydrates, with less red and processed meat and less foods high in saturated fat, salt and free sugars.

The dietary data collection tool in the NDNS rolling programme is designed to capture nutritional differences in foods and drinks rather than differences in processing. The tool is under continuous review as part of the NDNS contract, so there is an opportunity to make changes to data capture to achieve better estimates of UPF intake. However, this is not straightforward and would require data on the presence and amounts of additives such as emulsifiers and non-sugar sweeteners within many individual foods.

SACN will keep the topic under annual review and consider again at SACN's next horizon scan meeting in 2026. Going forwards, SACN will focus its assessment on RCTs and good quality PCS (particularly those that consider the mechanism of UPF on health outcomes and provide data both adjusted and unadjusted for energy intake).

5.4 Recommendations

SACN has made the following recommendations in the context of existing UK government dietary recommendations.

On balance, most people are likely to benefit from reducing their consumption of processed foods high in energy, saturated fat, salt and free sugars and low in fibre. This is consistent with previous SACN recommendations. It is based on the nutrient content of many UPFs and concerns raised in relation to health.

SACN reiterates its existing advice in relation to processed foods, particularly in relation to minimising intake of sugar-sweetened beverages and the avoidance of high intakes of red and processed meat.

SACN reiterates its recommendations on sugar and NSS. See the 2025 position statement on NSS for full list of these (SACN, 2025).

It is recommended that government:

- considers strategies and actions to implement SACN's existing recommendations on processed foods (as table 3)
- considers whether the inclusion of messaging on processing improves dietary intakes, particularly in relation to reducing consumption of processed foods that are HFSS, without unintended adverse consequences
- compels industry to make processing data publicly available to enable monitoring and further research on associations with health outcomes - publicly available data are required on:
    - the amounts of individual additives such as emulsifiers and NSS within food products
    - the specific processing methods used
- monitor the consumption of individual additives such as emulsifiers and NSS in the UK diet, particularly among high consuming and vulnerable groups
- continue to review opportunities to monitor consumption of processed foods within NDNS

5.5 Research recommendations

As presented in section 3.3, SACN is aware of considerable ongoing research on this topic, both nationally and internationally. SACN encourages research funders to focus attention on the priority areas highlighted by SACN in its 2023 position statement and by the expert roundtables held in November 2023 as outlined above.

Further research is needed to refine the current UPF classification system (that is NOVA) to better identify foods and food categories where the risk to health is greatest.

As suggested by the subgroup analyses described in this evidence update, further consideration of subgroups within NOVA groups, particularly the UPF category, and health outcomes may help delineate principal mechanisms.

As noted in its 2023 position statement, SACN recommends that studies should take a formal approach to consistently identify and adjust for relevant potential confounders and mediators. In addition, studies should present findings with and without adjustment for energy.

SACN has made a number of research recommendations specifically in relation to NSS (SACN, 2025).

6. Suggested citation

The suggested citation is:

Scientific Advisory Committee on Nutrition. Processed foods and health: SACN's rapid evidence update. 2025.

7. SACN's role and membership

The role of SACN is to provide independent scientific advice on and risk assessments of nutrition and related health issues. It advises the 4 UK health departments, and other government departments and agencies.

Membership of SACN and the register of members' interests at the time of publication is provided in the 'SACN annual report 2024'. The SACN annual report and SACN's code of practice is available on the SACN webpage.

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Annex 1: excluded studies that used NDNS data

The following studies were identified within alerts for publications considering processed food consumption using National Diet and Nutrition Survey (NDNS) data, but were not included for the following reasons:

Watanabe and others (2024): an “integrative review” on “Influence of culinary skills in the dietetic pattern: ultra-processed foods consumption and Mediterranean diet adherence”. In this review, the only study using NDNS data had already been included in the SACN position statement and so was not included.

Sandall and others (2023): authors manually reviewed a database of all products from the food categories contributing to energy intake from UPF in the UK from the NDNS (2008–2014) for the presence of emulsifiers. The study did not estimate overall UPF intake, so was not included.

Chavez-Ugalde and others (2023): an abstract on “Prevalence and trends in consumption of ultra-processed food among UK adolescents aged 11 to 18 years: National diet and nutrition survey 2008/09 to 2018/19, a repeat cross-sectional study” was identified. This was not included as it was only an abstract. To note this has now been published (Chavez-Ugalde and others, 2024). Estimates of UPF intake in adolescents align with estimates identified in the 2023 SACN position statement.

Dicken and others (2023): a systematic review on “Who consumes ultra-processed food? A systematic review of sociodemographic determinants of ultra-processed food consumption from nationally representative samples”. Only one study used NDNS data, and it had already been included in the SACN position statement, so was not included.

Annex 2: eligibility criteria updated for SACN horizon scan

Table 4a: eligibility criteria for an updated search to identify evidence on associations between processed foods/UPF consumption and health outcomes

Category	Include	Exclude
Population	Studies including healthy adult and/or child populations and studies including otherwise healthy overweight/obese participants.	Studies including non-healthy populations (participants with specified medical conditions), for example type 2 diabetes, hypertension, cardiovascular disease.
Intervention/exposure	Comparison of consumption of unprocessed/minimally processed/processed (NOVA 1, 2 or 3) versus ultra-processed (NOVA 4) and comparison of intakes (high versus low) of UPF (NOVA 4). Also, classification system has been clearly defined by authors.	Studies not evaluating the consumption of processed foods and studies evaluating single food groups (for example sugar sweetened beverages or processed meats). Also, studies that do not clearly report a specific classification system.
Outcomes	Any health outcome including diet quality, energy intake, eating rate	None
Study type and design	SRs and/or MAs of RCTs, PCS, SRs and/or MAs that include mixed observational study design and PCS and/or RCT evidence has been analysed separately to other study design and URs.	SRs and/or MAs of mixed study designs that do not perform separate analysis of PCS and/or RCTs and all other primary study designs.
Literature type	Peer-reviewed papers published in scientific or medical journals.	Protocols, commentaries, editorials, letters to the editor, grey literature (PhD theses, extended abstracts, conference proceedings and so on), or other non-peer-reviewed publications.
Date	Published 12 January 2023 to present	Published before 12 January 2023

Category	Include	Exclude
Language	English	Languages other than English

Table 4b: eligibility criteria for a search to identify evidence on subgroup and substitution analysis

Category	Include	Exclude
Population	Studies including healthy adult and/or child populations and studies including otherwise healthy overweight/obese participants.	Studies including non-healthy populations (participants with specified medical conditions), for example type 2 diabetes, hypertension, cardiovascular disease.
Intervention/exposure	Comparison of consumption of unprocessed/minimally processed/processed (NOVA 1, 2 or 3) versus ultra-processed (NOVA 4) and comparison of intakes (high versus low) of UPF (NOVA 4). Also, classification system has been clearly defined by authors.	Studies not evaluating the consumption of processed foods and studies evaluating single food groups (for example sugar sweetened beverages or processed meats). Also, studies that do not clearly report a specific classification system.
Outcomes	Any health outcome including diet quality, energy intake, eating rate	None
Study type and design	Primary studies that have conducted substitution analysis where UPFs are substituted with non-UPF and subgroup analysis where UPFs are split into food categories.	Studies that have not conducted either substitution or subgroup analysis.
Literature type	Peer-reviewed papers published in scientific or medical journals.	Protocols, commentaries, editorials, letters to the editor, grey literature (PhD theses, extended abstracts, conference proceedings and so on), or other non-peer-reviewed publications.
Date	Published July 2019 to present	Published earlier than July 2019

Category	Include	Exclude
Language	English	Languages other than English

Table 4c: eligibility criteria for search to identify RCT evidence

Category	Include	Exclude
Population	Studies including healthy adult and/or child populations and studies including otherwise healthy overweight/obese participants.	Studies including non-healthy populations (participants with specified medical conditions), for example type 2 diabetes, hypertension, cardiovascular disease.
Intervention/exposure	Comparison of consumption of unprocessed/minimally processed/processed (NOVA 1, 2 or 3) versus ultra-processed NOVA 4) and comparison of intakes (high versus low) of UPF (NOVA 4). Also, classification system has been clearly defined by authors.	Studies not evaluating the consumption of processed foods and studies evaluating single food groups (for example sugar sweetened beverages or processed meats). Also, studies that do not clearly report a specific classification system.
Outcomes	Any health outcome including diet quality, energy intake, eating rate	None
Study type and design	RCTs only.	Any other study design.
Literature type	Peer-reviewed papers published in scientific or medical journals.	Protocols, commentaries, editorials, letters to the editor, grey literature (PhD theses, extended abstracts, conference proceedings and so on), or other non-peer-reviewed publications.
Date	Published July 2019 to present	Published earlier than July 2019

Category	Include	Exclude
Language	English	Languages other than English

Annex 3: search strategies to identify evidence

Search strategies to identify evidence examining the relationship between 2 or more levels of food processing and health outcomes were as follows.

Database: Ovid MEDLINE(R) ALL 1946 to 4 March 2024

Number	Searches	Results
1	((ultra-process* or ultraprocess*) adj3 food*).tw,kw.	1,707
2	(processed adj3 food*).tw,kw.	7,043
3	((overprocess* or over-process*) adj3 food*).tw,kw.	5
4	*Food, Processed/	167
5	*Fast Foods/	1,793
6	1 or 2 or 3 or 4 or 5	8,533
7	exp *Diet/	154,098
8	intake*.tw,kw.	341,728
9	consum*.tw,kw.	631,171
10	(diet* adj3 (habit* or pattern* or practice* or poor or unhealthy or behavio?r*)).tw,kw.	52,334
11	7 or 8 or 9 or 10	996,844
12	6 and 11	5,271
13	systematic review.pt.	254,001
14	meta analysis.pt.	196,138
15	limit 12 to "reviews (maximizes specificity)"	167
16	13 or 14 or 15	339,899
17	12 and 16	177
18	limit 17 to (english language and yr="2023 -Current")	57
19	("umbrella review" or "meta review" or metareview).tw,kw.	2,185
20	12 and 19	5
21	limit 20 to (english language and yr="2015 -Current")	5
22	"randomized controlled trial".pt.	609,669
23	controlled clinical trial.pt.	95,572

Number	Searches	Results
24	("randomi#ed controlled trial" or "randomi#ed clinical trial" or rct or "randomi#ed trial" or "controlled clinical trial").ti.	150,562
25	22 or 23 or 24	737,768
26	12 and 25	156
27	limit 26 to (english language and yr="2015 -Current")	115
28	subgroup*.tw.	319,408
29	"subgroup analys*".kw.	452
30	28 or 29	319,497
31	12 and 30	109
32	limit 31 to (english language and yr="2015 -Current")	90
33	substitut*.tw.	381,823
34	"substitution analys*".kw.	22
35	33 or 34	381,828
36	12 and 35	133
37	limit 36 to (english language and yr="2015 -Current")	99

Database: Embase 1974 to 4 March 2024

#	Searches	Results
1	((ultra-process* or ultraprocess*) adj3 food*).tw,kw.	2,109
2	(processed adj3 food*).tw,kw.	8,630
3	((overprocess* or over-process*) adj3 food*).tw,kw.	6
4	*processed food/	374
5	*ultra-processed food/	845
6	*fast food/	2,414
7	1 or 2 or 3 or 4 or 5 or 6	11,181
8	exp *Diet/	128,493
9	intake*.tw,kw.	452,230
10	consum*.tw,kw.	788,000
11	(diet* adj3 (habit* or pattern* or practice* or poor or unhealthy or behavio?r*)).tw,kw.	68,444
12	8 or 9 or 10 or 11	1,237,495
13	7 and 12	7,185
14	limit 13 to "reviews (maximizes specificity)"	183
15	limit 13 to (meta analysis or "systematic review")	221
16	14 or 15	258
17	limit 16 to (english language and yr="2023 -Current")	79
18	("umbrella review" or "meta review" or metareview).tw,kw.	2,320
19	13 and 18	6
20	limit 19 to (english language and yr="2015 -Current")	6
21	exp controlled clinical trial/	1,006,569
22	("randomi#ed controlled trial" or "randomi#ed clinical trial" or rct or "randomi#ed trial" or "controlled clinical trial").ti.	186,176
23	21 or 22	1,035,830
24	13 and 23	311
25	limit 24 to (english language and yr="2015 -Current")	266
26	subgroup*.tw.	470,803
27	"subgroup* analys*".kw.	655

#	Searches	Results
28	26 or 27	470,932
29	13 and 28	151
30	limit 29 to (english language and yr="2015 -Current")	127
31	substitut*.tw.	449,576
32	"substitution analys*".kw.	20
33	31 or 32	449,580
34	13 and 33	171
35	limit 34 to (english language and yr="2015 -Current")	134

Database: Food Science and Technology Abstracts 1969 to March 2024

#	Searches	Results
1	((ultra-process* or ultraprocess*) adj3 food*).ti,ab.	1,039
2	(processed adj3 food*).ti,ab.	11,523
3	((overprocess* or over-process*) adj3 food*).ti,ab.	16
4	processed foods/	46,124
5	Ultra-processed Foods/	303
6	fast foods/	2,720
7	1 or 2 or 3 or 4 or 5 or 6	56,065
8	diet/	81,163
9	intake*.ti,ab.	107,686
10	consum*.ti,ab.	246,352
11	(diet* adj3 (habit* or pattern* or practice* or poor or unhealthy or behavio?r*)).ti,ab.	21,426
12	8 or 9 or 10 or 11	342,401
13	7 and 12	16,576
14	systematic reviews/	3,600
15	meta-analysis/	5,519
16	("systematic review" or "meta analysis").ti.	10,664
17	14 or 15 or 16	11,684

#	Searches	Results
18	13 and 17	240
19	limit 18 to (yr="2023 -Current" and english)	89
20	("umbrella review" or "meta review" or metareview).ti,ab.	196
21	13 and 20	2
22	limit 21 to (yr="2015 -Current" and english)	2
23	randomized controlled trials/	2,216
24	("randomi#ed controlled trial" or "randomi#ed clinical trial" or rct or "randomi#ed trial" or "controlled clinical trial").ti.	5,120
25	23 or 24	6,620
26	13 and 25	237
27	limit 26 to (yr="2015 -Current" and english)	218
28	subgroup*.ti,ab.	7,018
29	13 and 28	155
30	limit 29 to (yr="2015 -Current" and english)	118
31	substitut*.ti,ab.	31,270
32	13 and 31	571
33	limit 32 to (yr="2015 -Current" and english)	406

PubMed

Search: (((food, processed[MeSH Major Topic]) OR (fast food[MeSH Major Topic])) OR ((((((("nova"[Title/Abstract]) OR ("processed food"[tiab:~3])) OR ("ultraprocessed food"[tiab:~3])) OR ("ultra processed food"[tiab:~3])) OR ("overprocessed food"[tiab:~3])) OR ("over processed food"[tiab:~3]))) AND ((((((((diet[MeSH Major Topic]) OR (intake*[Title/Abstract])) OR (consum*[Title/Abstract])) OR (dietary habit[Title/Abstract])) OR (dietary pattern[Title/Abstract])) OR (poor diet[Title/Abstract])) OR (unhealthy diet[Title/Abstract])) OR (dietary behavio?r[Title/Abstract]))

Combined with:

- filters: Meta-Analysis, Systematic Review, from 2023 – 2024
- filters: Randomized Controlled Trial, from 2015 - 2024
- search: ((umbrella review[Title/Abstract]) OR (meta review[Title/Abstract])) OR (metareview[Title/Abstract])
- search: subgroup*[Title/Abstract]

Annex 4: registered ongoing and completed RCTs and PCS identified

Search for a study on ClinicalTrials.gov using the NCT number.

NCT number	Study design	Title	Status	Study results	Primary completion date
NCT06017986	RCT	The Effect of Processing on Food Reward	Recruiting	No results available	1 July 2025
NCT06113146	RCT	Impact of the Eating Rate of Ultra-processed Foods on Dietary Intake Behavior and Metabolic Responses	Recruiting	No results available	1 October 2024
NCT06252701	RCT	Diet and Depression	Recruiting	No results available	October 2026
NCT06310603	RCT	Determinants and Outcomes of High vs. Low Ultra-processed Feeding	Recruiting	No results available	15 May 2024
NCT06314932	RCT	Role of Ultra-processed Foods in Modulating the Effect of Mediterranean Diet	Not yet recruiting	No results available	October 2024
NCT06338631	PCS	Early Detection of Renal Abnormalities in Metabolically Healthy and Unhealthy Weight Excess" (OB-KID)	Recruiting	No results available	31 December 2025
NCT06353009	RCT	Effect of a Single Ultra-Processed Meal on Myocardial Endothelial Function Assessed With Positron Emission Tomography	Completed	No results available	28 April 2023
NCT06518863	RCT	Ultra-Processed Foods and Executive Function	Recruiting	No results available	30 August 2024

NCT number	Study design	Title	Status	Study results	Primary completion date
NCT06538831	RCT	Impact of Ultra-processed Foods on Cardiometabolic Risk Factors (NOVA)	Not yet recruiting	No results available	30 June 2027