Universidade de São Paulo
Faculdade de Saúde Pública

Consumo de alimentos ultraprocessados, qualidade nutricional da dieta e obesidade na população australiana

Priscila Pereira Machado

Tese apresentada ao Programa de Pós-Graduação em Nutrição em Saúde Pública para obtenção do título de Doutor em Ciências.

Área de concentração: Nutrição em Saúde Pública

Orientador: Prof. Tit. Carlos Augusto Monteiro

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Dedico este trabalho à minha família. São do dia-a-dia no nosso restaurante e dos almoços de domingo em torno da mesa minhas memórias mais bonitas de afeto e da comida de verdade.

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RESUMO

Machado PP. Consumo de alimentos ultraprocessados, qualidade nutricional da dieta e obesidade na população australiana. [Tese de doutorado]. São Paulo: Faculdade de Saúde Pública, Universidade de São Paulo; 2019.

Introdução: Este estudo é parte do projeto temático “Consumo de alimentos ultraprocessados, perfil nutricional da dieta e obesidade em sete países”. O rápido aumento nas vendas de alimentos ultraprocessados em paralelo ao aumento nas prevalências de obesidade e outras doenças crônicas não-transmissíveis (DCNTs) tem sido observado em todo o mundo, inclusive na Austrália. Objetivo: Esta tese tem como objetivo estudar o consumo de alimentos ultraprocessados e sua influência sobre a qualidade nutricional da dieta e a ocorrência de obesidade na população australiana. Métodos: Estudo transversal em que foram analisados dados de consumo alimentar de uma amostra representativa da população australiana com dois ou mais anos de idade participantes da pesquisa *National Nutrition and Physical Activity Survey* (2011-12) (n=12.153). Todos os itens de consumo alimentar, coletados por meio de dois recordatórios de 24-horas, foram classificados nos quatro grupos da classificação NOVA, que considera a extensão e o propósito do processamento industrial de alimentos (alimentos in natura e minimamente processados, ingredientes culinários processados, alimentos processados, e alimentos ultraprocessados). Alimentos ultraprocessados são formulações industriais de substâncias extraídas ou derivadas de alimentos, em sua maioria de uso exclusivamente industrial, contendo pouco ou nenhum alimento inteiro e tipicamente adicionados de corantes, aromatizantes e outros aditivos cosméticos. O primeiro manuscrito da tese descreve o consumo de alimentos ultraprocessados na Austrália (população ≥2 anos de idade) e sua associação com a ingestão de nutrientes preditores de obesidade e outras DCNTs (i.e. açúcar livre, gorduras total, saturada e *trans*, fibra, sódio, potássio, e densidade energética da fração sólida da dieta). O segundo manuscrito explora a contribuição de alimentos ultraprocessados para a ingestão e o consumo excessivo (≥10% do total energético) de açúcar livre em diferentes grupos etários (crianças de 2-5 anos de idade, crianças de 6-11 anos, adolescentes (12-19 anos), adultos de 20-64 anos e idosos ≥65 anos). O terceiro manuscrito analisa a associação entre o consumo de alimentos ultraprocessados e a ocorrência de obesidade em adultos australianos. Resultados: Alimentos ultraprocessados foram os que mais contribuíram para o consumo alimentar diário do conjunto da população (42,0% do total de energia), sendo as crianças maiores de cinco anos e adolescentes os maiores consumidores desses alimentos (53,1% e 54,3% do total energético, respectivamente). Com o aumento da participação de alimentos ultraprocessados na dieta, esses alimentos tendem a substituir os alimentos in natura e minimamente processados e suas preparações culinárias. Associações diretas, significativas ($p<0,001$) e relações dose-resposta foram observadas entre o consumo de alimentos ultraprocessados e o conteúdo ou probabilidade de consumo inadequado de açúcar livre, gorduras total, saturada e *trans*, sódio e densidade energética da dieta, ao passo que o inverso foi observado para a ingestão de fibra e potássio. Em todos os grupos etários observou-se a associação direta e estatisticamente significativa ($p<0,001$) entre quintos de consumo de alimentos ultraprocessados e o conteúdo de açúcar livre na dieta, bem como o consumo excessivo deste nutriente. Associações diretas, significativas ($p<0,05$) e relações dose-resposta foram observadas entre o consumo de alimentos ultraprocessados e indicadores de obesidade após controle para as variáveis de confusão estudadas. Adultos australianos do quintil superior de consumo de alimentos ultraprocessados apresentaram maior índice de massa corporal (0,97 kg/m^2, IC 95% 0,42; 1,51), maior circunferência da cintura (1,92 cm, IC 95% 0,57; 3,27) e maiores chances de serem obesos (IMC$\geq$30kg/m^2) (OR=1,61, IC 95% 1,27; 2,04) ou apresentarem obesidade abdominal (OR=1,38, IC 95% 1,10; 1,72) em comparação àqueles do quintil inferior. Conclusões: Na Austrália, a elevada contribuição de alimentos ultraprocessados na dieta impacta negativamente no consumo dos grupos de alimentos não-ultraprocessados e em todos os nutrientes preditores de DCNTs, se relaciona ao consumo excessivo de açúcares livres em todas as faixas etárias e está associado à ocorrência de obesidade em adultos. Este estudo soma ao corpo crescente de evidências que mostram que o consumo de alimentos ultraprocessados está associado a uma deterioração geral das dietas e à ocorrência ou aumento no risco de obesidade, e sugere que a diminuição do consumo de alimentos ultraprocessados pode trazer benefícios substanciais para a qualidade da dieta e indicadores de obesidade na Austrália.

Palavras-chave: Processamento de alimentos. Alimento ultraprocessado. Qualidade da dieta. Açúcar livre. Obesidade. Austrália.

ABSTRACT

Machado PP. Consumption of ultra-processed foods, nutritional dietary quality and obesity in the Australian population. [Thesis]. São Paulo: "Faculdade de Saúde Pública, Universidade de São Paulo"; 2019.

Introduction: This study is part of the thematic project "Consumption of ultra-processed foods, dietary nutrient profile and obesity in seven countries". A rapid simultaneous increase in the sales of ultra-processed foods and the prevalence of obesity and other diet-related non-communicable diseases (NCDs) has been observed worldwide, including in Australia. Objective: This thesis aims to describe the consumption of ultra-processed foods, and its influence on the nutritional dietary quality and the risk of obesity in the Australian population. Methods: Cross-sectional study in which dietary intakes of a nationally representative sample of the Australian population aged 2+ years from the National Nutrition and Physical Activity Survey (2011-12) were evaluated (n=12,153). Food items collected through two 24-hour recalls were classified into the four groups of the NOVA system, a food classification based on the extent and purpose of industrial food processing (unprocessed and minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed foods). Ultra-processed foods are industrial formulations of substances extracted or derived from foods, mostly of exclusive industrial use, with little if any whole food and typically added of flavours, colours and other cosmetic additives. Manuscript 1 describes the consumption of ultra-processed foods in Australia (population aged ≥2 years) and its association with intake of nutrients linked to NCDs (i.e. free sugars, total, saturated and trans fats, fibre, sodium, potassium and dietary energy density). Manuscript 2 explores the contribution of ultra-processed foods to the intake and excessive intake (≥10% of total energy) of free sugars among different age groups (children aged 2-5 years, children aged 6-11 years, adolescents (12-19 years old), adults aged 20-64 years and elderly ≥65 years old). Manuscript 3 assesses the association between ultra-processed food consumption and obesity indicators among Australian adults. Results: Ultra-processed foods had the highest energy contribution in the overall Australian diet (42.0% of energy intake), with older children and adolescents the highest consumers of these foods (53.1% e 54.3% of energy intake, respectively). As ultra-processed food consumption increases, these foods tend to displace unprocessed and minimally processed foods and their culinary preparations. Significant ($p<0.001$) direct dose-response associations were found between the dietary share of ultra-processed foods and the dietary content of or the probability of inadequate intake of free sugars, total, saturated and trans fats, sodium and the dietary energy density, whilst the inverse was found in the intake of fibre and potassium. Among all age groups, a positive and statistically significant ($p<0.001$) linear association was found between quintiles of ultra-processed food consumption and both the intake of free sugars and the excessive free sugars intake. Significant ($p<0.05$) direct dose-response associations between the dietary share of ultra-processed foods and indicators of obesity were found after adjusting for all studied confounders. Australian adults in the highest quintile of ultra-processed food consumption had higher body mass index (0.97 kg/m^2, 95%CI 0.42; 1.51), greater waist circumference (1.92 cm, 95%CI 0.57; 3.27), and higher odds of being obese (BMI$\geq$30kg/m^2) (OR=1.61, 95%CI 1.27; 2.04) and presenting abdominal obesity (OR=1.38, 95%CI 1.10; 1.72) compared with those in the lowest quintile of consumption. Conclusions: In Australia, the high energy contribution of ultra-processed foods impacts negatively on the intake of non-ultra-processed foods and on all nutrients linked to NCDs, drives excessive free sugars intake among all age groups, and is associated with obesity among adults. This study adds to the growing evidence that ultra-processed food consumption is associated with an overall deterioration of the nutritional quality of diets, and with or increases the risk of obesity, as well as suggests that decreasing the dietary share of ultra-processed foods would substantially improve the diet quality and obesity indicators in Australia.

Keywords: Food processing. Ultra-processed food. Diet quality. Free sugar. Obesity. Australia.

SUMÁRIO

APRESENTAÇÃO

Esta tese compõe o projeto temático "Consumo de alimentos ultraprocessados, perfil nutricional da dieta e obesidade em sete países", iniciado em 2016 no âmbito do Núcleo de Pesquisas Epidemiológicas em Nutrição e Saúde da Universidade de São Paulo (NUPENS/USP), em colaboração com pesquisadores filiados a outras universidades brasileiras e estrangeiras. Este projeto temático dá continuidade à linha de pesquisa pioneira do NUPENS/USP que investiga os efeitos do processamento industrial de alimentos sobre a saúde da população. A equipe do NUPENS/USP, liderada pelo Professor Carlos Monteiro, propôs critérios para classificar os alimentos segundo a extensão e o propósito do processamento industrial a que foram submetidos antes de sua aquisição e consumo pelos indivíduos.

Desde a primeira publicação apresentando esta classificação, em 2009, posteriormente denominada NOVA, e a proposição do projeto temático, em 2015, diversos estudos com base em dados gerados por inquéritos de compras ou vendas de alimentos já mostravam resultados consistentes com a hipótese de que a participação de alimentos ultraprocessados na dieta poderia comprometer a qualidade nutricional da alimentação e aumentar o risco de doenças crônicas não transmissíveis, em particular de obesidade. No entanto, não haviam sido publicados, até o momento, estudos com base em inquéritos de consumo efetivo individual de alimentos.

Inquéritos que coletaram simultaneamente dados antropométricos e de consumo efetivo de alimentos em amostras representativas de populações foram identificados na Austrália, Brasil, Canadá, Chile, Colômbia, Estados Unidos e Reino Unido, e estes países foram então inseridos no projeto temático. Desde então, teses de doutorado e mais de quinze manuscritos já foram produzidos como parte do projeto. Esta tese, que liderou o módulo australiano do projeto temático, é fruto de um trabalho iniciado com o meu ingresso no curso de doutorado, em 2016, em ampla articulação com os demais projetos realizados pelo NUPENS/USP, e em colaboração com pesquisadores australianos. Esta parceria foi fortalecida durante o meu estágio em pesquisa no exterior realizado na Austrália entre maio/2018 e abril/2019 na

University of Melbourne, sob a supervisão do Dr. Gyorgy Scrinis, Professor da Faculdade de Ciências Agrárias e coordenador do *Food Policy Research Group*, e em visita técnica a pesquisadores parceiros da *University of Sydney* e *Deakin University*. Destaca-se a importante participação destes pesquisadores parceiros em todas as etapas de desenvolvimento dos manuscritos da tese.

Esta tese buscou estudar o consumo de alimentos ultraprocessados e sua influência sobre a qualidade nutricional da dieta e a ocorrência de obesidade na população australiana, e está composta por seis capítulos. O primeiro capítulo apresenta o referencial teórico que fundamentou este estudo, em especial o cenário epidemiológico global e australiano das doenças crônicas não transmissíveis, e sua relação com as transformações no sistema alimentar contemporâneo.

O segundo capítulo explicita os objetivos da tese. A concretização desses objetivos está apresentada em três manuscritos elaborados a partir da pesquisa de representatividade nacional *National Nutrition and Physical Activity Survey* conduzida entre maio de 2011 e junho de 2012 (NNPAS 2011-12), como parte da *Australian Health Survey* conduzida pelo *Australian Bureau of Statistics*.

O capítulo 3 consiste no manuscrito “Ultra-processed foods and recommended intake levels of nutrients linked to non-communicable diseases in Australia: evidence from a nationally representative cross-sectional study” (em inglês), que descreve o consumo de alimentos ultraprocessados na Austrália e sua associação com a ingestão de nutrientes preditores de obesidade e outras doenças crônicas não-transmissíveis. Este artigo está aceito para publicação no periódico *BMJ Open*. Resultados oriundos deste estudo foram apresentados nos congressos *21st International Congress of Nutrition*, realizado em 2017 na Argentina, *Food Futures Conference*, realizado em 2018 na Austrália, e no *XVIII Congreso latinoamericano de Nutrición (SLAN)*, realizado em 2018 no México.

O capítulo 4 consiste no manuscrito “Ultra-processed food consumption drives excessive free sugars intake among all age groups in Australia” (em inglês), que explora a contribuição de alimentos ultraprocessados para a ingestão e o consumo excessivo de açúcares livres em diferentes grupos etários. Este artigo foi submetido para publicação no periódico *European Journal of Nutrition* e encontra-se em fase de revisão. Resultados oriundos deste estudo foram apresentados no congresso *XVIII Congreso latinoamericano de Nutrición (SLAN)*, realizado em 2018 no México.

O capítulo 5 consiste no manuscrito "Ultra-processed food consumption and obesity in the Australian adult population (2011/12)" (em inglês), que analisa a associação entre consumo de alimentos ultraprocessados e ocorrência de obesidade em adultos australianos. Este artigo será submetido para publicação no periódico *International Journal of Obesity*. Resultados oriundos deste estudo foram apresentados no congresso *Public Health Prevention Conference*, realizado em 2019 na Austrália.

No sexto e último capítulo da tese apresento as considerações finais, incluindo as principais implicações dos achados dos estudos para as pesquisas e políticas públicas na área de alimentação, nutrição e saúde.

Por fim, destaca-se que esta tese foi desenvolvida no Programa de Pós-Graduação em Nutrição em Saúde Pública da Faculdade de Saúde Pública (FSP) da USP, que tem como objetivo "a formação de recursos humanos para docência e pesquisa, tanto básica/experimental como aplicada, e para a atuação em políticas públicas em alimentação e nutrição, buscando contribuir para o avanço da ciência e para a promoção da saúde da população"[1]. Para tal, destaco minha participação em atividades de pesquisa no Brasil e no exterior como membro do NUPENS/USP e pesquisadora visitante da *University of Melbourne*, e em atividades de docência como estagiária do Programa de Aperfeiçoamento de Ensino junto à disciplina de graduação "Epidemiologia Nutricional" da FSP/USP, sob supervisão do Prof. Carlos Monteiro, e de banca de Trabalho de Conclusão de Curso do curso de graduação em Nutrição da FSP/USP. Ainda, colaborei com dois documentos importantes da área com vistas ao fomento de políticas públicas para a promoção da alimentação adequada e saudável em âmbito global: o "Global Nutrition Report 2018" e o "Ultra-processed foods, diet quality, and health using the NOVA classification system" para a *Food and Agriculture Organization of the United Nations* (FAO). Também relevante, participei da organização de eventos realizados na FSP/USP e atuei em espaços decisórios da FSP/USP enquanto representante discente.

[1] Programa de Pós-Graduação em Nutrição em Saúde Pública da FSP/USP. Apresentação. [http://www.fsp.usp.br/pos/?cat=27]

1 INTRODUÇÃO

Em 2016, a Assembleia Geral das Nações Unidas proclamou a Década de Ação sobre a Nutrição (2016-2025), colocando o enfrentamento a todas as formas de má nutrição como desafio global para se atingir os Objetivos do Desenvolvimento Sustentável (FAO, 2016a). O reconhecimento da nutrição como elemento central para o desenvolvimento sustentável é consequência do cenário alarmante experienciado globalmente. Uma em cada três pessoas sofre hoje com ao menos uma das três grandes formas de má nutrição - desnutrição, deficiências de micronutrientes, e/ou sobrepeso, obesidade e doenças crônicas não transmissíveis (DCNTs) causadas pela má alimentação (tais como doença cardiovasculares, diabetes tipo 2 e câncer) – gerando impactos negativos expressivos sobre o desenvolvimento econômico, social e ambiental das nações (FAO, 2016a).

A redução da desnutrição e das deficiências de micronutrientes (NCD-RisC, 2017), embora ainda bastante tímida, mostra o aparente compromisso com a redução da fome no mundo (FAO, 2016a). Por outro lado, nas últimas quatro décadas, a prevalência global de obesidade quase triplicou (NCD-RisC, 2017), tornando-se uma pandemia global (Swinburn et al., 2019; 2011). Em 2016, estimou-se que cerca de 5 milhões de mortes foram atribuídas ao sobrepeso e obesidade ao redor do mundo (GBD 2016 Risk Factor Collaborators, 2017).

Dentre os países de alta renda que apresentaram maiores aumentos na prevalência da obesidade no período de 1980 a 2013, destacam-se os Estados Unidos, o Reino Unido e a Austrália (NG et al., 2014). Na Austrália, pesquisas nacionais da década de 90 já indicavam aumento dramático na prevalência de obesidade (Swinburn & Wood, 2013). Essa tendência segue sendo observada no período recente: 19% da população australiana era obesa em 1995, 27% em 2012, e 31% em 2018 (ABS, 2019; Keating et al., 2015). Atualmente, a Austrália ocupa o quinto lugar entre os países mais obesos da Organização para a Cooperação e Desenvolvimento Econômico (OECD) (OECD, 2017) e se as tendências atuais continuarem, estima-se que em 2025, 35% dos adultos australianos serão obesos (Hayes et al., 2017). Este dado é alarmante dado que índice de massa corporal (IMC) elevado é o segundo maior fator de risco para mortalidade na Austrália (AIHW, 2017) e atualmente 89% das mortes no país são devido a DCNTs, particularmente doenças cardiovasculares (28%) e câncer (29%) (WHO, 2018a). Também de grande importância, destaca-se que a prevalência de diabetes na Austrália triplicou entre 1989 e 2015 (de 1,5% para 4,7%) (AIHW, 2018).

A explicação para o aumento na prevalência global de DCNTs, em particular de obesidade, parece encontrar-se nas transformações no sistema alimentar contemporâneo. A globalização financeira e o livre comércio, a expansão das atividades comerciais e políticas das corporações transnacionais de alimentos, e a própria (in)ação política e regulatória em âmbitos nacionais e global, impulsionados pelo crescimento econômico e populacional, a urbanização e o desenvolvimento da ciência e tecnologia de alimentos, têm fomentado novas formas de produção, processamento, distribuição, compra e consumo de alimentos (Monteiro et al., 2018; Global Panel, 2016; Monteiro et al., 2013; Malik; Willett; Hu, 2013; Stuckler et al., 2012; Ludwig, 2011; WHO, 2009; Thow, 2009; Popkin, 2006). Como consequência, tem-se observado em escala global o enfraquecimento de padrões alimentares tradicionais e sua substituição por padrões alimentares marcados pelo consumo de alimentos prontos para o consumo e com elevado grau de processamento industrial (Monteiro et al., 2013; Popkin, 2006).

Para melhor compreender essas mudanças no sistema alimentar e o seu impacto na saúde da população, e na ausência de alternativas consistentes, Monteiro (2009) propôs critérios para classificar os alimentos segundo a extensão e o propósito do processamento industrial a que foram submetidos antes de sua aquisição e consumo pelos indivíduos. Esta classificação, posteriormente denominada NOVA, foi descrita formalmente e aplicada pela primeira vez em 2010 (Monteiro et al., 2010) e, desde então, vem sendo detalhada e aprimorada (Monteiro et al., 2019a; Monteiro et al., 2016; Moubarac et al., 2014a).

A classificação NOVA aparece como uma abordagem alternativa ao agrupamento dos alimentos de acordo com sua composição nutricional. Este último, baseado em um paradigma reducionista da nutrição (*nutritionism* (Scrinis, 2013)), tornou-se obsoleto e incapaz de responder à complexidade dos problemas contemporâneos de nutrição resultantes das mudanças nos padrões alimentares e condições de saúde da população (Ridgway et al., 2019; FAO, 2016b, Tapsell, 2016; Jacobs & Tapsell, 2013; Scrinis, 2013; Jacobs et al., 2003). A classificação NOVA, por outro lado, baseia-se em uma visão holística de alimentação, e foi criada a partir da tese de que características do processamento industrial de alimentos são capazes de explicar as relações contemporâneas entre alimento, nutrição e as condições de saúde das populações (Monteiro et al., 2018). Esta tese é reconhecida em documentos oficiais das Nações Unidas (Monteiro et al., 2019b; FAO, 2016b; 2015; PAHO, 2015), em periódicos científicos de relevância internacional (Swinburn et al., 2019; Lawrence & Baker, 2019; Moodie et al., 2013; Ludwig, 2011) e literatura crescente (Monteiro et al., 2019b), e orientou a elaboração de guias alimentares de países como o Brasil (Brasil, 2014), Uruguai (Uruguay, 2016) e Peru (Serrano & Curi, 2019).

A classificação NOVA aloca todos os itens alimentares passíveis de consumo pelos indivíduos em quatro grandes grupos mutualmente excludentes (Monteiro et al., 2019a; Monteiro et al., 2016; Monteiro et al., 2010). O primeiro é composto pelos alimentos in natura e minimamente processados. Esses últimos vêm a ser alimentos in natura submetidos a processos físicos ou biológicos, como remoção de partes não desejadas, refrigeração, congelamento, pasteurização, fermentação não alcoólica, que não incluem a adição de sal, açúcar, óleos, gorduras e outras substâncias ao alimento original. Processos mínimos aumentam a duração dos alimentos in natura, preservando-os e tornando-os apropriados para armazenamento, seguros, comestíveis ou mais agradáveis ao paladar. Exemplos de alimentos do grupo 1 incluem arroz e outros cereais, feijões e outras leguminosas, carnes, peixes, leite, ovos, frutas, raízes e tubérculos, vegetais, nozes e sementes.

O segundo grupo é composto pelos ingredientes culinários processados. Este grupo inclui substâncias extraídas diretamente de alimentos do grupo 1 ou da natureza, tais como o sal, o açúcar, os óleos, e as gorduras. Por meio de processos como prensagem, moagem, secagem, ou refino, esses ingredientes são produzidos com o propósito de serem utilizados nas cozinhas das casas ou restaurantes para temperar e cozinhar alimentos in natura ou minimamente processados.

O terceiro grupo, de alimentos processados, abrange produtos prontos para o consumo e manufaturados essencialmente com a adição de sal, açúcar, óleo, gorduras ou outra substância do grupo 2 a alimentos do grupo 1, utilizando métodos de preservação ou fermentação. Alimentos processados incluem conservas de legumes e frutas, carnes salgadas, peixes conservados em óleo ou água e sal, castanhas adicionadas de sal ou açúcar, queijos e pães do tipo artesanal. O propósito do processamento, neste caso, é o de aumentar a duração do alimento in natura e/ou criar alternativas para o seu consumo. Quando consideras partes da alimentação, bebidas alcoólicas fabricadas pela fermentação alcoólica de alimentos do grupo 1, tais como cerveja e vinho, são classificadas neste grupo.

O quarto grupo da classificação NOVA, de alimentos ultraprocessados, é constituído por formulações industriais de substâncias extraídas ou derivadas de alimentos, em sua maioria de uso exclusivamente industrial, contendo pouco ou nenhum alimento inteiro e tipicamente adicionados de corantes, aromatizantes e outros aditivos cosméticos. A fabricação de alimentos ultraprocessados envolve diversos processos e diferentes indústrias: começa com a extração de substâncias existentes no grupo 1, tais como óleos, gorduras, açúcares, amidos, fibras e proteínas. Algumas dessas substâncias são submetidas à hidrólise, hidrogenação ou outras modificações químicas. Processos subsequentes envolvem a combinação destas substâncias modificadas (ex. gordura hidrogenada, amido modificado) e não modificadas (ex. açúcar, óleo vegetal, amido) em processos que dão forma, estrutura e composição ao produto, tais como extrusão, moldagem e pré-fritura. Comumente esses alimentos são adicionados de aditivos ‘cosméticos’, isto é, substâncias cuja função é simular atributos sensoriais (cor, sabor, aroma e textura) dos alimentos do grupo 1 e suas preparações culinárias, e/ou ocultar atributos sensoriais indesejáveis no produto final causados pelo processamento ou embalagem. Exemplos de aditivos cosméticos incluem corantes, aromatizantes, adoçantes artificiais, realçadores de sabor, emulsificantes e espessantes. Por fim, estes produtos recebem embalagens sofisticadas, geralmente feitas de materiais sintéticos (ex. bisfenóis). Ao final, essas formulações usualmente incluem cinco ou mais ingredientes e contêm pouco ou nenhum alimento in natura ou minimamente processado.

Centenas ou milhares de variedades de alimentos ultraprocessados são lançadas no mercado mundial todos os anos (Spiteri; Olstad; Woods, 2018; Monteiro et al., 2013), incluindo vários tipos de bebidas adoçadas, *snacks* salgados e doces, bolos e tortas, sobremesas industrializadas, cereais matinais, *fast foods*, pratos prontos para aquecer, como pizzas, hambúrgueres e *nuggets* congelados, ou diluir, como sopas e “macarrão instantâneo” desidratados. A manufatura de alimentos ultraprocessados visa essencialmente criar produtos altamente lucrativos capazes de substituir alimentos in natura ou minimamente processados e suas preparações culinárias (Monteiro et al., 2019a; Monteiro et al., 2016; Monteiro et al., 2010).

A natureza dos processos e os ingredientes utilizados na manufatura de alimentos ultraprocessados, tais como a destruição da matriz alimentar, a remoção parcial ou total de água, e o uso de grandes quantidades de sal, açúcar, gorduras e aditivos cosméticos, tornam estes alimentos nutricionalmente desbalanceados, com alta densidade energética, altamente palatáveis e aditivos (Spiteri; Olstad; Woods, 2018; Fardet, 2016; Ni Mhurchu et al., 2016; Luiten et al., 2015; Ludwig, 2011). Ademais, alimentos ultraprocessados são convenientes, acessíveis, portáteis, duráveis, apresentados em embalagens atrativas atreladas a estratégias de marketing agressivas. Estes atributos reforçam uma suposta superioridade dos alimentos ultraprocessados com relação aos demais alimentos. Todos esses fatores contribuem para que os alimentos ultraprocessados substituam alimentos in natura ou minimamente processados, como também incentivam o consumo excessivo de calorias (Monteiro et al., 2019a; PAHO, 2015; Monteiro et al., 2013; Swinburn et al., 2011; Ludwig, 2011; Monteiro et al., 2011), condições potencialmente relacionadas ao aumento do risco de obesidade e DCNTs (WHO, 2018b; PAHO, 2015).

Estudos utilizando a classificação NOVA documentaram mudanças temporais nas vendas de alimentos ultraprocessados e encontraram aumentos expressivos no consumo desses alimentos no Brasil (Monteiro et al., 2011; Martins et al., 2013), México (Marrón-Ponce et al., 2018), Suécia (Juul e Hemmingsson, 2015), Canadá (Moubarac et al., 2014b), Chile (Crovetto & Uauy, 2012), Noruega (Solberg; Terragni; Granheim, 2015), em 79 países de alta e média renda (Monteiro et al., 2013) e em 13 países latino-americanos (PAHO, 2015). Em países de alta renda com tradições culinárias menos acentuadas, os ultraprocessados já são hegemônicos na alimentação (Monteiro et al., 2013b). Nestes países com sistemas alimentares industrializados, como os Estados Unidos, Reino Unido e Canadá, alimentos ultraprocessados perfazem 58%, 57% e 48% do consumo energético diário, respectivamente (Steele et al., 2016; Rauber et al., 2018; Moubarac et al., 2017). Em países onde os alimentos in natura e minimamente processados ainda são a base da alimentação da população, como o Brasil, Chile, Colômbia e México, alimentos ultraprocessados correspondem a 20-30% do consumo energético total (Louzada et al., 2017; Cediel et al., 2018; Parra et al., 2019; Marrón-Ponce et al., 2017).

De forma geral, tem-se observado que dietas baseadas em alimentos ultraprocessados apresentam maior densidade energética, mais açúcar livre, gordura total, saturada e *trans*, menos fibras e menor teor de micronutrientes do que dietas com baixa participação desses alimentos. Isso foi documentado em estudos utilizando dados de pesquisas de compras de alimentos no Brasil (Monteiro et al., 2011), Canadá (Moubarac et al., 2013a), Chile (Crovetto et al., 2014) e Espanha (Latasa et al., 2017), e inquéritos populacionais de consumo alimentar individual realizados no Brasil (Louzada et al., 2018; Louzada et al., 2015a; Louzada et al., 2015b), Canadá (Moubarac et al., 2017), Chile (Cediel et al., 2018), Colômbia (Parra et al., 2019), Estados Unidos (Steele et al., 2016; Steele et al., 2017), França (Julia et al., 2017), Japão (Koiwai et al., 2019), México (Marrón-Ponce et al., 2019), Reino Unido (Rauber et al., 2018) e Taiwan (Chen et al., 2018). Esses dados são relevantes considerando o corpo crescente de evidências relacionando consumo inadequado destes nutrientes críticos e o risco de obesidade e doenças crônicas (WHO, 2013; WCRF, 2007).

Dentre os fatores de risco nutricionais com evidência mais robusta quanto à sua associação com o desenvolvimento de obesidade e DCNTs no cenário atual, destaca-se a ingestão de açúcares livres (Ludwig & Ebbeling, 2018; WHO, 2015; Te Morenga et al., 2013, Malik et al., 2013). Açúcares livres compreendem monossacarídeos e dissacarídeos adicionados na manufatura de alimentos e bebidas ou pelo consumidor (açúcares de adição), e aqueles presentes naturalmente em mel, xaropes e concentrados de fruta (WHO, 2015). Existem evidências de que o consumo de alimentos ultraprocessados leva ao consumo excessivo de açúcares livres ou de adição no Brasil (Louzada et al., 2015a), Canadá (Moubarac et al., 2017), Chile (Cediel et al., 2018), Colômbia (Parra et al., 2019), Estados Unidos (Steele et al., 2016) e Reino Unido (Rauber et al., 2018).

Para além do impacto negativo sobre a qualidade nutricional das dietas, o consumo de alimentos ultraprocessados tem sido relacionado com IMC elevado e obesidade em âmbito global. O consumo de alimentos ultraprocessados foi associado com incidência de obesidade em uma coorte com nove anos de seguimento de adultos universitários na Espanha (Mendonça et al., 2016), e com IMC aumentado e obesidade em estudos transversais com amostras representativas de adultos americanos (Juul et al., 2018), canadenses (Nardocci et al., 2018), e adolescentes e adultos brasileiros (Louzada et al., 2015c). Estudo ecológico envolvendo 19 países europeus observou associação positiva entre disponibilidade domiciliar de alimentos ultraprocessados e as prevalências nacionais de obesidade entre adultos (Monteiro et al., 2017). Resultado similar também foi encontrado em estudo brasileiro (Canella et al., 2014). Associação positiva entre aumentos anuais na venda de alimentos ultraprocessados e aumentos anuais na média populacional do IMC de adultos foi observada em estudo envolvendo 80 países de alta e média renda (Vandevijvere et al., 2019), e em estudo anterior envolvendo 12 países latino-americanos (PAHO, 2015).

Relação causal entre o consumo de alimentos ultraprocessados e o ganho de peso foi investigada em recente ensaio clínico randomizado realizado nos Estados Unidos. No estudo conduzido por Hall e colaboradores (2019), envolvendo 20 adultos com média de 31 anos de idade e peso estável, os participantes seguindo a dieta baseada em alimentos ultraprocessados consumiram 508 ± 106 calorias/dia a mais do que participantes seguindo a dieta baseada em alimentos in natura ou minimamente processados. Ademais, os participantes ganharam, em média, 0.9 ± 0.3 kg durante a dieta ultraprocessada, e perderam, em média, 0.9 ± 0.3 kg durante a dieta não-ultraprocessada (Hall et al., 2019).

Na Austrália, tem-se observando nos últimos anos um aumento no consumo de alimentos com alta densidade energética em paralelo ao aumento na prevalência de obesidade (Keating et al., 2015; ABS, 2014; Rangan et al., 2009). Resultados da pesquisa mais recente sobre o consumo alimentar da população indicam que mais de um terço das calorias consumidas são provenientes de *'discretionary foods'*, alimentos manufaturados pela indústria com baixa qualidade nutricional (ABS, 2014). Ademais, foram estes alimentos os maiores responsáveis pelo consumo de açúcar de adição na população australiana de 4 a 50 anos (Lei et al., 2016).

Dados de vendas anuais per capita de alimentos ultraprocessados entre os anos de 2000 e 2013 situam a Australasia, que compreende a Austrália e Nova Zelândia, como a segunda maior consumidora desses alimentos entre as sete regiões analisadas. As vendas per capita de alimentos ultraprocessados na Australasia são menores apenas das vendas registradas na América do Norte (Estados Unidos e Canadá), mas enquanto nesta última região observa-se tendência de queda, na Australasia as vendas per capita/ano aumentaram de 192 kg para 200,5 kg entre 2000 e 2013. Consumindo 208,3 kg/per capita por ano em 2013, a Austrália ocupa o sexto lugar nas vendas de alimentos ultraprocessados entre os 80 países analisados (PAHO, 2015). Ao encontro destes achados, estudo com dados da pesquisa domiciliar australiana observou que os gastos com alimentos ultraprocessados cresceram cerca de 5% entre 1989 e 2010 no país (Venn et al., 2016).

Estudos australianos lançam luz sobre alguns fatores que potencialmente contribuem para o consumo de alimentos ultraprocessados no país: a substituição do preparo das refeições em casa pela compra de alimentos ultraprocessados prontos para o consumo e o maior gasto com refeições fora de casa (Venn et al., 2016), o aumento do tamanho das porções desses alimentos (Zheng et al., 2016), maior disponibilidade de ultraprocessados e frequência de descontos a esses produtos em supermercados (Zorbas et al., 2019; Cameron; Waterlander; Svastisalee, 2014; Thorton et al., 2012), elevada publicidade destes produtos dirigida ao público infantil (Kelly et al., 2019; Sacks et al., 2014), e uso indevido de alegações saudáveis em mais da metade dos rótulos de alimentos ultraprocessados (Dickie; Woods; Lawrence, 2019; Ni Mhurchu et al., 2016).

Embora a Austrália seja reconhecida como um país com tradição na proposição de políticas públicas de saúde e com mais de 20 anos de experiência em ações para redução da obesidade, sendo referência para diversos países (Swinburn & Wood, 2013), autores destacam a ineficiência e barreiras para consolidação destas ações e políticas propostas até o momento (Chung et al., 2012; Shill et al., 2012; Elliot et al., 2014). Apesar da relevância do ambiente obesogênico como determinante do consumo de alimentos ultraprocessados e da ocorrência de obesidade na Austrália (Swinburn & Wood, 2013; Swinburn et al., 2011), e do crescente reconhecimento do papel do processamento de alimentos como preditor da qualidade nutricional da dieta e saúde das populações (Monteiro et al., 2019b; 2018), o consumo de alimentos ultraprocessados, seu impacto sobre a qualidade nutricional da dieta e sua associação com a obesidade não haviam sido estudados na Austrália até o presente momento.

Destaca-se que este estudo faz parte do projeto temático *Consumo de alimentos ultraprocessados, perfil nutricional da dieta e obesidade em sete países*, liderado por pesquisadores brasileiros que tem como objetivo estudar o padrão de consumo de alimentos ultraprocessados e sua influência sobre o perfil nutricional da dieta e o risco de obesidade na população de sete países.

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2 OBJETIVOS

2.1 OBJETIVO GERAL

Estudar o consumo de alimentos ultraprocessados e sua influência sobre a qualidade nutricional da dieta e a ocorrência de obesidade na população australiana.

2.2 OBJETIVOS ESPECÍFICOS

- Descrever o consumo de alimentos ultraprocessados na Austrália e sua associação com a ingestão de nutrientes preditores de doenças crônicas não-transmissíveis.

- Avaliar a associação entre o consumo de alimentos ultraprocessados e a ingestão de açúcares livres em diferentes grupos etários na Austrália.

- Analisar a associação entre consumo de alimentos ultraprocessados e ocorrência de obesidade em adultos australianos.

3 CONSUMO DE ALIMENTOS ULTRAPROCESSADOS NA AUSTRÁLIA E SUA ASSOCIAÇÃO COM A INGESTÃO DE NUTRIENTES PREDITORES DE DOENÇAS CRÔNICAS NÃO-TRANSMISSÍVEIS

Este capítulo apresenta o artigo "*Ultra-processed foods and recommended intake levels of nutrients linked to non-communicable diseases in Australia: evidence from a nationally representative cross-sectional study*" de autoria de Priscila Pereira Machado, Eurídice Martinez Steele, Renata Bertazzi Levy, Zhixian Sui, Anna Rangan, Julie Woods, Timothy Gill, Gyorgy Scrinis, e Carlos Augusto Monteiro. O artigo foi aceito para publicação na revista *BMJ Open* em 10 de julho de 2019 (comprovante em anexo).

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Ultra-processed foods and recommended intake levels of nutrients linked to non-communicable diseases in Australia: evidence from a nationally representative cross-sectional study

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ABSTRACT

Objectives: This study aimed to describe the consumption of ultra-processed foods in Australia and its association with intake of nutrients linked to non-communicable diseases (NCDs). **Design**: Cross-sectional study. Setting: National Nutrition and Physical Activity Survey (2011-12). **Participants**: 12,153 participants aged 2+ years. **Main outcome measures**: Average dietary content of nutrients linked to NCDs and the prevalence of intakes outside levels recommended for the prevention of NCDs. **Data analysis**: Food items were classified according to the NOVA system, a classification based on the nature, extent and purpose of industrial food processing. The contribution of each NOVA food group and their subgroups to total energy intake was calculated. Mean nutrient content of ultra-processed food and non-ultra-processed food fractions of the diet were compared. Across quintiles of the energy contribution of ultra-processed foods, differences in the intake of nutrients linked to NCDs, as well as in the prevalence of intakes outside levels recommended for the prevention of NCDs were examined. **Results**: Ultra-processed foods had the highest dietary contribution (42.0% of energy intake), followed by unprocessed or minimally processed foods (35.4%), processed foods (15.8%) and processed culinary ingredients (6.8%). A positive and statistically significant linear trend was found between quintiles of ultra-processed food consumption and intake levels of free sugars (standardized β 0.43, $p<0{\cdot}001$), total (β 0.08, $p<0{\cdot}001$), saturated (β 0.18, $p<0{\cdot}001$) and trans fats (β 0.10, $p<0{\cdot}001$), sodium (β 0.21, $p<0{\cdot}001$), and diet energy density (β 0.41, $p<0{\cdot}001$), while an inverse relationship was observed for dietary fibre (β -0.21, $p<0{\cdot}001$) and potassium (β -0.27, $p<0{\cdot}001$). The prevalence of non-recommended intake levels of all studied nutrients increased linearly across quintiles of ultra-processed food intake, notably from 22% to 82% for free sugars, from 6% to 11% for trans fat, and from 2% to 25% for dietary energy density, from the lowest to the highest ultra-processed food quintile. **Conclusions**: The high energy contribution of ultra-processed foods impacted negatively on the inta7ke of non-ultra-processed foods and on all nutrients linked to NCDs in Australia. Decreasing the dietary share of ultra-processed foods would substantially improve the diet quality in the country and help the population achieve recommendations on critical nutrients linked to NCDs.

Keywords: Food processing; Diet; Quality of diet; Food consumption; Australia

Strengths and limitations of this study

- Use of the most up-to-date, individual-level dietary survey data taken from a nationally representative sample of Australian children and adults, increasing generalisability.
- Use of the NOVA food classification system applied to disaggregated food codes, enabling to assess underestimated food groups and comparisons among different countries.
- The assessment of the contribution of foods according to the level of processing to daily intake of nutrients linked to NCDs provided novel evidence to improve the diet quality in Australia.
- Dietary data obtained by 24-h recalls are subject to errors.
- Some items may have been misclassified due to inconsistencies of information indicative of food processing in the datasets.

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Competing interests declaration

None.

Author’s contribution

C.A.M., E.M.S., P.P.M., and R.B.L. designed the research; E.M.S., P.P.M., and Z.S. took care of data management and analyses; A.R., C.A.M., E.M.S., G.S., J.W., P.P.M., R.B.L, T.P.G., Z.S. interpreted the data; P.P.M. wrote the first draft of the manuscript; A.R., C.A.M., E.M.S., G.S., J.W., P.P.M., R.B.L, T.P.G., Z.S revised each draft for important intellectual content. All authors read and approved the final manuscript.

3.1 INTRODUCTION

Obesity and chronic non-communicable diseases (NCDs), such as cardiovascular diseases, type 2 diabetes and some cancers, are the main causes of premature death and disability in Australia and the world(1; 2; 3). Important risk factors driving most NCDs are dietary nutritional imbalances(4), which appear to be due to changes in global food systems(5; 6; 7). The increasing supply, distribution and consumption of cheap, palatable, accessible, convenient and highly marketed mass-produced products have led to the displacement of dietary patterns based on fresh and minimally processed foods(8; 9).

The NOVA system, a food classification based on the nature, extent and purpose of industrial food processing, has been applied worldwide to understand the impact of modern industrial food systems on human health(10). Considered the most specific, coherent and comprehensive food classification system based on food processing(11), NOVA classifies foods into four groups: unprocessed and minimally processed foods, processed culinary ingredients, processed foods and ultra-processed foods(12). Ultra-processed foods are formulations of low-cost ingredients, many of non-culinary use, that result from a sequence of industrial processes (hence ‘ultra-processed’). Examples of ultra-processed foods include soft drinks, sweet and savory snacks such as fruit straps, potato crisps, confectionary, many breakfast cereals, microwaveable frozen meals, instant soups, fast food dishes and a myriad of new products launched in the market every year(9; 12). High amounts of salt, added sugars, fat and/or additives make them extremely palatable and habit-forming(13). They dispense with the necessity of culinary preparation and are omnipresent, which make them convenient and accessible. The aggressive and sophisticated marketing of ultra-processed foods amplifies their ‘advantages’ (convenience, branding, pricing) over unprocessed or minimally processed foods(8; 14).

In Australia, an increase in the consumption of high energy-dense, nutrient-poor foods has been observed–over the years(15; 16; 17). Sales data provided by the market research firm Euromonitor show that in 2013 Australia had the 6th highest per capita sales among the evaluated ultra-processed foods behind the U.S., Canada, Germany, Mexico and Belgium(14). Data from a nationally representative sample of the Australian households also showed that expenditure (as a percentage of the home food budget) on ultra-processed foods increased around 5% between 1989 and 2010[18].

Despite the evidence that indicates that the degree of food processing effectively predicts the nutritional quality of diets and their impact on obesity and NCDs[10; 14], the consumption of ultra-processed foods and their impact on the dietary nutrient profile has not been studied in Australia. This study aimed to characterize the overall and different patterns of ultra-processed food consumption in Australia, compare the nutrient profiles of ultra-processed and non-ultra-processed fractions of the diet and describe the association between ultra-processed food consumption and intake of nutrients linked to non-communicable diseases (NCDs).

3.2 METHODS

Data source

The data source for this study was the National Nutrition and Physical Activity Survey (NNPAS) 2011-12, part of the 2011-13 Australian Health Survey. This nationally representative cross-sectional survey studied a randomly selected, national sample of the Australian population using a complex, stratified, multistage probability cluster sampling design with selection of strata, households and people within households. The NNPAS was conducted between May 2011 and June 2012 on 9,519 households where 12,153 Australians aged 2 years and above were interviewed[19].

Data on food intake were collected as part of NNPAS based on two 24-hour dietary recalls administered by trained and experienced interviewers using the Automated Multiple-Pass Method. The first recall was applied through a face-to-face interview (n=12,153) while the second recall (n=7,735) was applied via a telephone interview conducted 8 days or more after the first interview[19]. For children under 15 years of age, parents/guardians were used as proxies, previously found to be valid instruments to assess energy intake among children aged 4 to 10 years old[20]. Where permission was granted by a parent/guardian, adolescents aged 15–17 years old were interviewed in person. If permission was not granted, questions were answered by an adult. Energy and nutrient intakes were estimated based on the Australian

Food and Nutrient Database (AUSNUT 2011-13), which contains information for 5,740 foods and beverages consumed during the survey[21].

Food classification

Reported single food items and the underlying ingredients of culinary preparations (handmade recipes) were classified according to NOVA food classification system into the following four groups (and subgroups within these groups): Group 1 - Unprocessed or minimally processed foods (e.g. rice and other cereals, meat, fish, milk, eggs, fruit, roots and tubers, vegetables, nuts and seeds); Group 2 - Processed culinary ingredients (e.g. sugar, plant oils and butter); Group 3 - Processed foods (e.g. processed breads and cheese, canned fruit and fish, and salted and smoked meats); Group 4 - Ultra-processed foods (e.g. confectionaries, savoury snacks, fast food dishes, mass-produced packaged breads, frozen and ready meals and soft drinks)[10; 12].

Ultra-processed foods, which are the focus of interest in this study, as previously mentioned, are formulations of low-cost ingredients, many of non-culinary use, that result from a sequence of industrial processes. Processes underlying the manufacture of ultra-processed foods start with the extraction of substances existing in intact foods, such as oils, fats, sugars, starches, and protein. Intermediate processes may involve hydrolysis, hydrogenation and other chemical modifications of the extracted substances. Other steps include the assembling of modified (e.g. hydrogenated oils) and unmodified (e.g. sugar) substances using processes such as extrusion and pre-frying, the addition of additives, and sophisticated packaging with the frequent employment of novel synthetic materials[10; 12].

Food items were ultimately classified as ultra-processed if they contained ingredients found exclusively in these products. These ingredients are substances derived from foods but of non-culinary use (e.g.: protein isolates, modified starches, hydrogenated or interesterified oils), and classes of additives with cosmetic functions (e.g.: colorants, flavourings, artificial sweeteners, emulsifiers, thickeners, and bleaching, bulking, firming, gelling, glazing, foaming, and carbonating agents). The presence or absence of these ingredients was identified from auxiliary AUSNUT data sources (Food details file and Food recipe file)[21] and from list of ingredients obtained from food packages or from company websites (see Supplementary

Material Appendix 1 to 2). More information regarding how to identify ultra-processed foods can be found elsewhere[10; 12].

For all food items judged to be a culinary preparation, the recipes were disaggregated using the AUSNUT 2011-2013 Food Recipe File[21], enabling the classification of composite foods into all NOVA food groups. A total of 2,585 (45%) food codes were subject to disaggregation and this process was continued until all ingredients were single food items.

To classify all food items, two experts with Australian food and dietary intake knowledge applied the NOVA system to the AUSNUT 2011-13. All classifications were checked by another two independent food assessment experts and where classification discrepancies arose, these were discussed until consensus was reached amongst all researchers. The NOVA system was applied to the AUSNUT classification system that considers a major (two-digit), sub-major (three-digit) or minor (five-digit) food group. The survey ID (eight-digit) assigned to each food item was used when it was not possible to discriminate the degree of food processing within a minor group (Table 1).

TABLE 1

When the classification of a food item was not clear (e.g. cake or cupcake, honey, commercial or homemade), the conservative alternative was chosen (homemade in this case, and thus disaggregated). Additional procedures were applied to classify breads with generic food item descriptions based on the sampling details information comprised in the AUSNUT 'Food details file'. Unlike other countries, many commercially produced breads in Australia are processed rather than ultra-processed, that is their ingredients do not include neither food substances of no culinary use, nor cosmetic additives. Of the 62 generic bread codes where the NOVA classification was not easily apparent, there were two generic bread codes that contributed the most to total bread energy intake (25% combined): i) Bread, from white flour, commercial, ii) Bread roll, from white flour, commercial. They were classified as ultra-processed foods since the samples that composed the AUSNUT 2011-13 were mostly of mass-produced branded breads with cosmetic additives. All the remaining infrequent breads were classified as processed as the conservative hypothesis (see details in the Supplementary Material Appendix 1 to 2).

Data analysis

The mean daily contribution of each NOVA food group and their subgroups to the total energy intake was calculated. Thereafter, the population was stratified into quintiles of the energy share of ultra-processed foods, with the lowest consumers belonging to the first quintile and the highest consumers to the fifth. The energy share of each NOVA food group and subgroup was estimated across those quintiles.

Considering the nutrients included in international guidelines (World Health Organization and World Cancer Research Fund) for the prevention of NCDs among all age groups, we assessed: the percentage of energy from free sugars and from fats (total, saturated and trans), the density of dietary fibre (g per 1,000 kcal), sodium (mg per 1,000 kcal), and potassium (mg per 1,000 kcal), and the dietary energy density (calculated as kcal per g, excluding beverages)[22; 23; 24; 25; 26]. The mean nutrient intake levels were calculated for the overall diet and for two diet fractions, one made up entirely of the ultra-processed foods, and the other made up of all the non-ultra-processed foods (that is, the sum of unprocessed or minimally processed foods, processed culinary ingredients and processed foods). Differences between the two diet fractions were analysed using tests of means for independent samples (t-test).

The mean nutrient intake levels for the overall diet were then compared across quintiles of the dietary energy provided by ultra-processed foods. Crude and adjusted standardized linear regression models were used to assess the direction and the statistical significance of the association of these quintiles with the nutrient intake levels. Standardized adjusted regression coefficients were obtained by regressing the nutrient intake levels on the quintiles of the dietary share of ultra-processed foods, and expressed in standard deviation units. For these analyses, the first 24-hour recall was used, which is suitable to estimate group means[27; 28].

Finally, we estimated, for the overall population and for quintiles of the dietary share of ultra-processed foods, the prevalence of nutrient intake levels that were outside the recommended levels for the prevention of NCDs: ≥10% of total energy intake for free sugar, ≥30% of total energy intake for total fat, ≥10% of total energy intake for saturated fat, ≥1% of total energy intake for trans fat, ≤12.5g/1,000kcal for dietary fibre, ≥1,000 mg/1,000 kcal for sodium, ≤1,755mg/1,000 kcal for potassium and ≥2.25 kcal/gram for dietary energy density[22; 23; 24; 25; 26]. For this analysis, intakes were adjusted by the Multiple Source Method (MSM)[29] to account for intra-person variability by considering the data from the second 24-h recall, which is the recommended approach to evaluate dietary adequacy[27]. Prevalence ratios from Poisson regression models were used to assess the magnitude of the associations between quintiles of energy contribution of ultra-processes foods and nutrient intakes. Wald and linear tests were used to assess the significance of variables in the models and to test trends across quintiles of ultra-processed food intake, respectively.

All regression models were adjusted for the following potential confounders: sex (male/female), age groups (2-5 years; 6-9 y; 10-18 y; 19-30 y; 31-50 y; 51-69 y; ≥70 y), Socio-Economic Index of Disadvantage for Areas (SEIFA – quintiles), educational attainment of respondents, for participants ≥18 years old, and of household reference persons otherwise (completed 9 years or below including never attended, completed 10 to 12 years with no graduate degree, completed 12 years with graduate degree), and geographical location (major cities of Australia, inner regional, and other, which includes outer regional, remote and very remote Australia).

Sensitivity analyses were carried out to account for exposure misclassification of breads. The counterfactual scenario simulated the effect in the direction, magnitude and the statistical significance of the association between the dietary share of ultra-processed foods and dietary content of nutrients linked to NCDs if all breads were classified in the processed food group.

Weighted analyses were performed using Stata survey module (version 14) to consider the effect of complex sampling procedures adopted in the NNPAS 2011-12 and in order to allow extrapolation of results for the Australian population (Stata Corp., College Station, United States).

This study was a secondary analysis using de-identified data from the ABS Basic Confidentialised Unit Record Files (CURFs), and permission to use the data was obtained. Ethics approval for the survey was granted by the Australian Government Department of Health and Ageing Departmental Ethnics Committee in 2011[19].

Patient and Public Involvement

This research was done without patient involvement.

3.3 RESULTS

In 2011-12, Australians aged 2 years and above consumed an average of 1,968 kcal per day, 35.4% of which were from the NOVA group of unprocessed or minimally processed foods, 6.8% from processed culinary ingredients, 15.8% from processed foods and 42.0% from the ultra-processed food group (Table 2).

TABLE 2

Meat, milk, cereal grains and flours, and fruits accounted for most of the energy of unprocessed or minimally processed foods consumed in Australia. Within processed culinary ingredients, most of the energy came from plant oils. Processed breads, beer, and wine were the highest contributors of energy amongst processed foods. Mass-produced packaged breads (4.8% of total daily intake), frozen and shelf stable ready meals (3.7%), fast food dishes (3.5%), and pastries, buns and cakes (3.3%) contributed most to dietary energy intake from ultra-processed foods (Table 2).

The mean dietary share of ultra-processed foods ranged from 12.8% of total daily intake for those in the lowest quintile of ultra-processed food intake, to 74.5% for those in the upper quintile of ultra-processed food intake (Table 3). The energy share of all subgroups belonging to the ultra-processed food group increased linearly across quintiles of ultra-processed food intake, in particular fast food dishes and ready meals showed a substantial increase (114 times and 22 times, respectively). An opposite trend for subgroups from the three remaining groups indicates that ultra-processed foods tend to progressively displace all other foods and culinary preparations as ultra-processed food intake increases (Table 3).

TABLE 3

A comparison of the nutrient profiles between the ultra-processed and non-ultra-processed fractions of the Australian diet can be seen in Table 4. The dietary fraction made up exclusively of ultra-processed items contained significantly more free sugars (4.7 times), sodium (2.9 times), was higher in diet energy density (1.9 times) and lower in potassium (1.7 times) and fibre content (1.4 times) than the non-ultra-processed fraction. The average content of fats in the diet fraction made of ultra-processed items was higher than in the dietary fraction made of non-ultra-processed items, except for trans fat content, although the magnitude of the differences was small: 32.1 vs. 30.4% for total fats, 12.7% vs. 11.6% for saturated fats, and 0.5% vs. 0.6% for trans fats.

TABLE 4

Table 5 presents the average nutrient content of the overall diet across quintiles of ultra-processed food intake. Both crude and adjusted regression coefficients show a positive and statistically significant linear trend between the dietary share of ultra-processed foods and the intake of free sugars, total, saturated and trans fats, sodium, and the dietary energy density while an inverse relationship was observed for the intake of dietary fibre and potassium. Stronger associations were found with free sugars ($\beta=0.43$, $p<0.001$), energy density ($\beta=0.41$, $p<0.001$), sodium ($\beta=0.21$, $p<0.001$), potassium ($\beta=-0.27$, $p<0.001$) and dietary fibre ($\beta=-0.21$, $p<0.001$). Stratified analyses showed that the association between the dietary share of ultra-processed foods and the intake of nutrients remained statistically significant among most age groups and both sex strata (data not shown).

TABLE 5

Table 6 shows the prevalence of non-recommended nutrient intake levels across quintiles of the dietary energy share of ultra-processed foods. In the highest quintile of ultra-processed food consumption, about 80% of the Australian population exceeded the upper limits recommended for free sugars, saturated fats, and sodium and over 85% did not meet the recommendation for dietary fibre and potassium. The prevalence of non-recommended intake levels of all nutrients increased linearly across quintiles of the dietary share of ultra-processed foods ($p<0.001$). Notably, from the lower to the upper quintile, the proportion of non-recommended intake levels increased from 22% to 82% for free sugars, from 6% to 11% for trans fat, and from 2% to 25% for dietary energy density.

The direction, magnitude and the statistical significance of the associations between the dietary share of ultra-processed foods and the risk of non-recommended intake levels of all studied nutrients did not change with adjustment for age, sex, educational attainment, socio-economic status and geographical location. We also categorised individuals with diet energy density higher than 1.25 kcal/g (World Cancer Research Fund recommends lowering this value as a public health goal)[26] and the proportion of non-recommended intake levels increased from 82% to 98% from the lower to the upper quintile (PR: 1.2; $p<0.001$ – data not shown).

Tables S1–S3 (available in the Supplementary Material Appendix 3) show results from the sensitivity analyses that considered all breads in the processed food group (11.6% of total energy intake from processed breads). Results show that potential ultra-processed bread misclassification may have led to a 4.8% maximum overestimation of energy intake from ultra-processed foods and to slight underestimations of the strength of associations between ultra-processed foods and free sugars, fats and dietary fibre, and overestimation of the association with sodium, potassium and diet energy density.

TABLE 6

3.4 DISCUSSION

In this analysis of nationally representative data, we found that ultra-processed foods contribute to more than 40% of total daily energy intake of Australians. These foods are predominantly mass-produced packaged breads, ready meals, fast food dishes and pastries, buns, and cakes. As ultra-processed food consumption increases, these foods tend to displace unprocessed and minimally processed foods and their culinary preparations, including the five core food groups recommended by the Australian Dietary Guidelines[30]. The dietary content of free sugars, total, saturated and trans fats, sodium and the dietary energy density, all increased significantly as the energy share of ultra-processed foods increased, while an inverse association was found for the dietary content of fibre and potassium. The prevalence of non-recommended intake levels of all studied nutrients linked to NCDs increased linearly across quintiles of ultra-processed food intake.

In other high-income countries, ultra-processed foods also dominate the diet: 57.9% of total energy intake in the United States[31], 56.7% in the United Kingdom[32], and 47.7% in Canada[33]. In Latin American high and middle-income countries, such as Chile[34], Brazil[35] and Mexico[36], unprocessed and minimally processed foods are still the basis of the population's diet and ultra-processed foods made up between 20% and 30% of total energy intake. This is despite sales of ultra-processed foods in Latin-American countries rising rapidly[14].

The strong association between the energy share of ultra-processed foods and dietary nutrient profiles predictive of increased risk of diet-related NCDs is seen across several high and middle-income countries[31; 32; 33; 34; 37; 38]. In Australia, the prevalence ratios of non-recommended nutrient intake levels among people in the fifth quintile of ultra-processed food consumption were higher in comparison with the U.S. (2.9 times more likely to exceed added sugars intake than the first quintile)[31] and the U.K. (1.1 times more likely to exceed free sugars and fibre intake)[32]. This is probably explained by differences in the dietary share of ultra-processed foods and also by the types of non-ultra-processed foods most consumed by first quintile ultra-processed food consumers in the countries (rather than by differences among higher consumers). While in Australia ultra-processed foods account for 13% of total energy intake in the lowest quintile of ultra-processed food consumption, in the U.S. and the U.K. this figure surpasses 30%[31; 32]. Australians with the lowest consumption of ultra-processed foods also consume more grains and vegetables than Americans and British.

To our knowledge, this is the first study to evaluate the association between the dietary contribution of ultra-processed foods and the overall NCD-related nutrient profile of diets in Australia, and the first to analyse the 2011-2012 survey data with this focus. In Australia, one-third (35%) of total daily energy consumed is from discretionary foods – defined as foods that are unnecessary in a healthy diet and which are generally energy dense and nutrient poor[30; 39]. The Australian Dietary Guidelines (ADGs) emphasise the importance of limiting the consumption of discretionary foods[30]. Although most discretionary foods are likely to be classified as ultra-processed foods, a considerable number of foods from the Five Food Groups recommended by the ADGs are classified as ultra-processed foods, including many breads, breakfast cereals, flavoured yoghurts and margarines.

Australia is experiencing a high prevalence of NCDs – more than 90% of the deaths are due to chronic diseases, notably cardiovascular diseases and cancer[3], and Australia has the fifth highest rate of obesity in the OECD (28% of the population aged +15 years)[40]. The evidence so far, from cross-sectional or cohort studies conducted in middle and high income countries, has shown a direct association between ultra-processed food consumption and obesity[41; 42; 43; 44;45], cancer[46], hypertension[47], dyslipidaemias[48], metabolic syndrome[49;50], and myocardial infarction and stroke (SROUR et al., unpublished results).

Considering the mounting body of research linking inadequate intake of critical nutrients and risk of chronic diseases[7; 26], and the persistent increase in the purchase of ultra-processed foods by the Australian population[18], our findings have implications for policy and practice. We showed that Australians who based their diet on unprocessed and minimally processed foods, and on culinary preparations made up with these foods, are more likely to achieve the nutrient intake levels internationally recommended for the prevention of NCDs. Therefore, there is a need for initiatives that combine the promotion of healthy foods with the reduction of ultra-processed food consumption[5; 7; 51; 52].

The presence of misleading nutrition and health claims on ultra-processed food labels in Australia[53; 54], the limitations of the Australian Health Star Rating System to support healthy choices in agreement with the ADGs[55] and the limits of the ultra-processed food reformulation to address unhealthy diets[56] reinforce the need for targeted strategies to reduce the consumption of ultra-processed foods[51]. Australia could adopt some of the lessons from its successful anti-smoking intervention[57] to the consumption of ultra-processed foods to help tackle the epidemic of chronic disease. This could entail restricting the sale of ultra-processed foods in schools, health care and other settings, considering taxation and pricing interventions, limiting promotion and advertising, particularly to children, improving food labelling and improving the retail environment[24; 51; 58; 59; 60].

The main strength of our study is the use of the most up-to-date, individual-level dietary survey data taken from a nationally representative sample of Australian children and adults, which increases the generalisability of our findings. The food classification system we used (NOVA) has been recognised as a relevant approach for linking dietary intakes and incidence of obesity and NCDs[10; 14]. In addition, we applied the classification to several disaggregated food codes in the AUSNUT 2011-13, enabling the assessment of food groups whose consumption has previously been underestimated[61], and comparisons with studies in different countries that applied the NOVA system[31; 32; 34; 37]. It is also important to highlight that the AUSNUT 2011-13 food composition database was specifically developed to reflect the food supply and food preparation practices during the period of the NNPAS 2011-12[21].

Nevertheless, potential limitations should be considered. Although we used the most recent, individual-level national survey to analyse Australian dietary intake, these data may not account for recent changes in the food supply or dietary habits in the country. Though household expenditure in ultra-processed foods increased from 2010 to 2016 in Australia[62], as well as the supply of those foods[9], no substantial changes in their nutrient profile could be identified[53; 63]. Therefore, the observed associations in our study will unlikely have changed in more recent years. Dietary data obtained by 24-h recalls are subject to errors given the tendency for people to misreport their food intake. Analysis of the NNPAS 2011-12 suggests sizeable misreporting[19], but the impact in the assessment of ultra-processed food consumption is unknown. Some studies suggest that unhealthy foods are more likely to be under-reported[64], which could have led to an underestimation of overall dietary contribution of ultra-processed foods or the prevalence of inadequate nutrient intake or may attenuate the magnitude of the association between both variables (should differential information bias exist).

Another potential limitation is that both the 24-h recall instrument and the food composition tables were not designed to evaluate the food consumption according to industrial processing. Therefore, despite the effort and systematic approach to apply the NOVA system properly into the AUSNUT 2011-13 dataset, some items may have been misclassified. However, to reduce misclassification several independent researchers reviewed the classification and any areas of misclassification were resolved by discussion and consensus. Additionally, in the case of breads, we carried out sensitivity analyses given their high contribution to the total energy intake in Australia, especially those types of breads with generic food descriptions in the AUSNUT dataset. Including information to characterize the processing of foods in dietary surveys, like brand and product name, preferably linked to a list of ingredients provided by a food supply survey or by the food industry, would help to assess dietary intake considering food processing[65].

3.5 CONCLUSION

In conclusion, ultra-processed foods accounted for more than 40% of energy consumed in Australia and they tend to displace all other foods and culinary preparations. The dietary share of ultra-processed foods impacted negatively on the intake of all nutrients linked to non-communicable diseases, being therefore a key metric to evaluate dietary patterns. The high dietary energy share of ultra-processed foods in Australia calls for actions targeting those products in order to increase the healthiness of food environments and reduce obesity and diet-related NCDs. Decreasing the dietary share of ultra-processed foods would substantially improve the diet quality in Australia and help the population achieve recommendations on critical nutrients linked to NCDs and foods recommended by the Australian Dietary Guidelines.

DATA AVAILABILITY STATEMENT

No additional data available.

3.6 REFERENCES

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3.7 TABLES

Table 1. Example of the AUSNUT 2011-13 food group classification and application of the NOVA system.

Major food group: two-digit food code	Sub-major food group: three-digit food code	Minor food group: five-digit food code	Survey ID: eight-digit food code	NOVA system classification
16 Fruit products and dishes	161 Pome fruit	16104 Pears, commercially sterile	16104009 Pear, canned in sugar syrup	Group 3 Processed Foods
			16104010 Pear, canned in intense sweetened liquid	Group 4 Ultra-processed foods

Table 2. Mean absolute and relative daily energy intake according to NOVA food groups. Australian population aged 2+ years (NNPAS 2011–2012) (n = 12,153).

(Continues)

NOVA Food Groups	Kcal	% of total energy intake
Unprocessed or minimally processed foods	**675.4**	**35.4**
Red meat and poultry	155.3	8.1
Milk and plain yoghurt	123.9	6.6
Cereal grains and flours	120.3	5.9
Fruits[a]	86.8	4.9
Vegetables	50.5	2.8
Pasta	45.4	2.3
Nuts and seeds	21.3	1.2
Potatoes and other tubers and roots	21.8	1.0
Eggs	19.2	1.0
Fish	15.2	0.8
Legumes	9.2	0.5
Other[b]	6.8	0.4
Processed culinary ingredients	**133.8**	**6.8**
Plant oils	59.2	3.0
Animal fats	37.6	1.8
Table sugar	30.8	1.6
Other[c]	6.2	0.3

Table 2. Mean absolute and relative daily energy intake according to NOVA food groups. Australian population aged 2+ years (NNPAS 2011–2012) (n = 12,153).

(Continuation)

NOVA Food Groups	Kcal	% of total energy intake
Processed foods	**310.5**	**15.8**
Processed breads	123.3	6.8
Beer and wine	80.1	3.6
Cheese	50.5	2.6
Bacon and other salted, smoked or canned meat or fish	22.6	1.2
Vegetables and other plant foods preserved in brine	8.6	0.5
Other[d]	25.5	1.2
Ultra-processed foods	**842.4**	**42.0**
Mass-produced packaged breads	89.3	4.8
Frozen and shelf stable ready meals[e]	70.8	3.7
Fast foods dishes[f]	75.8	3.5
Pastries, buns, and cakes	72.6	3.3
Breakfast cereals	62.0	3.2
Biscuits	59.0	3.1
Fruit drinks and iced teas	58.7	3.0
Confectionary	58.6	2.9
Sausage and other reconstituted meat products	49.0	2.4
Carbonated soft drinks	44.0	2.1
Milk-based drinks	42.8	2.1
Sauces, dressing and gravies	36.3	1.8
Salty snacks	34.1	1.6
Ice cream, ice pops and frozen yogurts	34.2	1.6
Margarine and other spreads	26.9	1.4
Alcoholic distilled drinks	12.2	0.5
Other[g]	16.8	0.9
Total	1968.0	100.0

1 kcal = 4.18 kJ
[a] Including freshly squeezed juices
[b] Including meat from other animals, teas, coffees and dried spices.
[c] Including honey, maple syrup (100%) and vinegar.
[d] Including salted or sugared nuts, seeds and dried fruits.
[e] Including frozen lasagna, pizza and other pastas and meals, and instant soups and noodles.
[f] Including hamburger, pizza and French fries from fast food places.
[g] Including ultra-processed cheese, baby food and baby formula.

Table 3. Percentage of total energy intake according to NOVA food groups across quintiles of the dietary share of ultra-processed foods. Australian population aged 2+ years (NNPAS 2011–2012) (n = 12,153). (continues)

NOVA Food Groups	Quintiles of the dietary contribution of ultra-processed foods (% of total dietary energy)¥				
	Q1	Q2	Q3	Q4	Q5
Unprocessed or minimally processed foods	**54.8**	**43.3**	**36.0**	**27.6**	**15.3***
Red meat and poultry	12.2	10.0	8.3	6.4	3.4*
Milk and plain yoghurt	7.7	7.7	6.9	6.3	4.2*
Cereal grains and flours	12.0	7.3	5.4	3.6	1.2*
Fruits[a]	7.1	5.8	5.2	4.1	2.4*
Vegetables	4.3	3.4	2.9	2.0	1.2*
Pasta	3.0	3.0	2.5	1.8	0.9*
Nuts and seeds	2.5	1.3	0.8	0.4	0.2*
Potatoes and other tubers and roots	1.5	1.5	1.3	1.1	0.6*
Eggs	1.4	1.2	1.0	0.9	0.5*
Fish	1.6	1.1	0.7	0.5	0.3*
Legumes	0.9	0.6	0.5	0.3	0.2*
Other[b]	0.7	0.5	0.4	0.3	0.2*
Processed culinary ingredients	**9.7**	**8.4**	**7.1**	**5.4**	**3.1***
Plant oils	5.0	3.7	3.2	2.2	1.1*
Animal fats	2.3	2.3	1.9	1.6	0.8*
Table sugar	1.9	2.0	1.7	1.4	1.0*
Other[c]	0.5	0.4	0.3	0.2	0.1*
Processed foods	**22.7**	**19.8**	**16.5**	**12.9**	**7.1***
Processed breads	9.0	8.1	7.1	6.1	3.6*
Beer and wine	6.8	4.8	3.5	1.9	0.8*
Cheese	3.0	3.2	2.8	2.5	1.5*
Bacon and other salted, smoked or canned meat or fish	1.6	1.5	1.3	1.0	0.5*
Vegetables and other plant foods preserved in brine	0.7	0.4	0.5	0.5	0.2*
Other[d]	1.6	1.6	1.3	0.9	0.6*

Table 3. Percentage of total energy intake according to NOVA food groups across quintiles of the dietary share of ultra-processed foods. Australian population aged 2+ years (NNPAS 2011–2012) (n = 12,153). (continuation)

NOVA Food Groups	Quintiles of the dietary contribution of ultra-processed foods (% of total dietary energy)¥				
	Q1	Q2	Q3	Q4	Q5
Ultra-processed foods	**12.8**	**28.4**	**40.4**	**54.1**	**74.5***
Mass-produced packaged breads	1.6	3.8	5.1	6.1	7.3*
Frozen and shelf stable ready meals[e]	0.4	1.4	2.7	5.1	8.7*
Fast foods dishes[f]	0.1	0.6	1.3	4.0	11.4*
Pastries, buns, and cakes	0.6	2.2	3.5	4.7	5.6*
Breakfast cereals	1.4	3.1	4.0	4.0	3.6*
Biscuits	1.1	2.3	3.2	4.0	4.7*
Fruit drinks and iced teas	1.1	2.3	3.1	3.9	4.8*
Confectionary	0.9	2.2	3.0	3.5	4.7*
Sausage and other reconstituted meat products	0.9	1.6	2.4	3.3	3.9*
Carbonated soft drinks	0.4	1.1	1.8	2.6	4.6*
Milk-based drinks	0.9	1.6	2.0	2.7	3.5*
Sauces, dressing and gravies	1.1	1.9	1.9	2.2	1.9*
Salty snacks	0.3	0.7	1.6	2.3	3.1*
Ice cream, ice pops and frozen yogurts	0.3	1.1	1.9	2.3	2.6*
Margarine and other spreads	0.9	1.4	1.5	1.7	1.5*
Alcoholic distilled drinks	0.1	0.3	0.3	0.6	1.2*
Other[g]	0.5	0.8	1.1	0.8	1.3*
Total	100.0	100.0	100.0	100.0	100.0

[a,b,c,d,e,f,g] The same as the previous table.

¥Percentage of total energy intake from ultra-processed foods. Mean (range): Q1= 12.8 (0 to 21.8); Q2= 28.4 (21.8 to 34.6); Q3= 40.4 (34.6 to 46.6); Q4= 54.1 (46.6 to 62.1); Q5= 74.5 (62.1 to 100).

*$p<0.05$ for linear trend across quintiles of dietary share of ultra-processed foods.

Table 4. Average nutrient content of the overall diet and of two diet fractions. Australian population aged 2+ years (NNPAS 2011–2012) (n = 12,153).

Nutrients	Overall diet		Ultra-processed food diet fraction		Non-ultra-processed food diet fraction[a]	
	Mean	(SE)	Mean	(SE)	Mean	(SE)
Free sugars (% of total energy)	11.7	(0.1)	21.6	(0.2)	4.6*	(0.1)
Total fats (% of total energy)	31.1	(0.1)	32.1	(0.2)	30.4*	(0.1)
Saturated fat (% of total energy)	12.0	(0.1)	12.7	(0.1)	11.6*	(0.1)
Trans fat (% of total energy)	0.6	(0.0)	0.5	(0.0)	0.6*	(0.0)
Dietary fibre (g/1,000 kcal)	11.5	(0.1)	9.7	(0.1)	13.2*	(0.1)
Sodium (mg/1,000 kcal)	1213	(6.4)	2475	(90.8)	859*	(6.3)
Potassium (mg/1,000 kcal)	1444	(6.6)	1055	(8.6)	1813*	(10.5)
Energy density (kcal/g)[b]	1.7	(0.0)	2.7	(0.0)	1.4*	(0.0)

SE: Standard Error
[a]It includes NOVA unprocessed or minimally processed foods, processed culinary ingredients and processed foods.
[b]Beverages excluded.
*p<0.001 for significant mean differences between the two fractions of the diet.

Table 5. Average nutrient content of the overall diet according to quintiles of the dietary share of ultra-processed foods. Australian population aged 2+ years (NNPAS 2011–2012) (n = 12,153).

Nutrients	Quintiles of the dietary contribution of ultra-processed foods (% of total dietary energy)[a]					Standardized regression coefficients[b]	
	Q1	Q2	Q3	Q4	Q5	Crude	Adjusted†
Free sugars (% of total energy)	5.8	9.2	11.7	14.0	17.7	0.45*	0.43*
Total fats (% of total energy)	30.1	31.1	30.5	31.6	32.2	0.08*	0.08*
Saturated fat (% of total energy)	10.3	11.7	12.0	12.8	13.1	0.21*	0.18*
Trans fat (% of total energy)	0.52	0.58	0.59	0.63	0.64	0.11*	0.10*
Dietary fibre (g/1,000 kcal)	13.3	12.3	11.8	10.7	9.4	-0.24*	-0.21*
Sodium (mg/1,000 kcal)	1053	1142	1216	1275	1384	0.21*	0.21*
Potassium (mg/1,000 kcal)	1674	1542	1465	1346	1177	-0.30*	-0.27*
Energy density (kcal/g)[c]	1.5	1.6	1.7	1.8	2.1	0.43*	0.41*

[a]Percentage of total energy intake from ultra-processed foods. Mean (range): Q1= 12.8 (0 to 21.8); Q2= 28.4 (21.8 to 34.6); Q3= 40.4 (34.6 to 46.6); Q4= 54.1 (46.6 to 62.1); Q5= 74.5 (62.1 to 100).
[b]Obtained with linear regression of the dietary nutrient content on the quintiles of the dietary share of ultra-processed foods, and expressed in standard deviation units.
[c]Beverages excluded.
†Adjusted for age, sex, educational attainment, socio-economic status and geographical location.
*Statistically significant p<0·001

Table 6. Prevalence (%) of non-recommended nutrient intake levels according to quintiles of the dietary share of ultra-processed foods Australian population aged 2+ years (NNPAS 2011–2012) (n = 12,153).

Quintiles of the dietary contribution of ultra-processed foods (% of total dietary energy)[a]	Non-recommended nutrient intake levels of:															
	Free sugars		**Total fat**		**Saturated fat**		**Trans fat**		**Dietary fibre**		**Sodium**		**Potassium**		**Energy density**	
	≥10% of energy		≥30% of energy		≥10% of energy		≥1% of energy		≤12.5g/ 1,000 kcal		≥1,000mg/ 1,000 kcal		≤1,755mg/ 1,000 kcal		≥2.25kcal/g	
	%	PR	%	PR	%	PR	%	PR	%	PR	%	PR	%	PR	%	PR
Q1 (lowest)	21.7	1.0	53.4	1.0	57.5	1.0	5.6	1.0	55.0	1.0	66.6	1.0	75.6	1.0	1.9	1.0
Q2	47.3	2.1	53.0	1.0	67.5	1.2	4.5	1.0	65.0	1.2	75.5	1.1	82.4	1.0	2.3	1.2
Q3	58.5	2.6	60.0	1.1	77.8	1.3	7.0	1.2	70.4	1.3	79.4	1.2	87.0	1.1	5.0	2.5
Q4	69.8	3.1	64.0	1.2	81.7	1.4	7.6	1.4	75.1	1.3	83.1	1.2	91.3	1.2	7.2	3.5
Q5 (highest)	82.1	3.6‡†	69.7	1.3‡†	84.3	1.4‡†	10.9	1.9‡†	85.6	1.5‡†	84.7	1.3‡†	93.1	1.2‡†	24.8	11.7‡†
Total	55.9	-	60.0	-	73.8	-	7.2	-	70.2	-	77.9	-	86.1	-	8.3	-

PR: Prevalence ratios adjusted for age, sex, educational attainment, socio-economic status and geographical location.

[a]The same as the previous table.

‡Significant linear trend across quintiles ($p<0.001$) in both unadjusted (coefficients not shown) and adjusted models.

†Wald test at 5% significance level.

3.8 SUPPLEMENTARY MATERIAL

Appendix 1. Manual of the application of NOVA system to the 2011-13 AUSNUT database

A novel processed food classification system applied to disaggregated food codes in the Australian Food Nutrient Database 2011-13

-- Manual –

Presentation

This project is part of the thematic project “Consumption of ultra-processed foods, dietary nutrient profile and obesity in seven countries”. The data source is the National Nutrition and Physical Activity Survey (NNPAS), conducted in 2011-12. This survey studied a random sample of the Australian population aged 2+ years (n=12,153).

Food consumption data were collected through two 24-h recalls. All foods and beverages purchased by households (after the exclusion of non-edible parts) were converted into energy and nutrients using data from the Australian Food Nutrient Database (AUSNUT) 2011-13 database.

Food items and/or the underlying ingredients were classified according to NOVA food classification system into the following four groups (and subgroups within these groups): Group 1 – Unprocessed or minimally processed foods (e.g. rice and other cereals, meat, fish, milk, eggs, fruit, roots and tubers, vegetables, nuts and seeds); Group 2 – Processed culinary ingredients (e.g. sugar, plant oils and butter); Group 3 – Processed foods (e.g. processed breads and cheese, canned fruit and fish, and salted and smoked meats); Group 4 – Ultra-processed foods (e.g. confectionaries, savoury snacks, fast food dishes, mass-produced packaged breads, frozen and ready meals and soft drinks). (Monteiro et al., 2018). The rationale underlying the classification is described elsewhere (Monteiro et al., 2016, 2018[2]).

[2]Monteiro, C. A.; Cannon, G.; Levy, R. B.; Moubarac, J-C.; Jaime, P.; Martins, A. P.; Canella, D.; Louzada, M. L.; Parra, D.; with Ricardo, C.; Calixto, G.; Machado, P.; Martins, C.; Martinez, E.; Baraldi, L.; Garzillo, J.; Sattamini, I. Nova. The star shines bright. [Food classification. Public health]. *World Nutrition*, v. 7, n. (1-3), p. 28-38, 2016. Monteiro, C. A.; Cannon, G.; Moubarac, J. C.; Levy, R. B.; Louzada, M. L. C.; Jaime, P. C. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutrition*, v. 21, n. 1, p. 5-17, 2018.

1 About AUSNUT 2011-13

AUSNUT 2011–13[3] is a set of files that enables food, dietary supplement and nutrient intake estimates to be made from the 2011–13 Australian Health Survey (AHS). It includes foods and dietary supplements consumed as part of the 2011–12 National Nutrition and Physical Activity Survey (NNPAS) and the 2012–13 National Aboriginal and Torres Strait Islander Nutrition and Physical Activity Survey (NATSINPAS) components of the AHS.

The complete AUSNUT 2011–13 contains the following 11 files:

Food details file – descriptive information on 5,740 foods and beverages to help users to identify where the nutrient data come from

Food composition database – 53 nutrient values for each of the 5,740 foods and beverages

Food recipe file – ingredient information on the 3,650 food and beverage recipes

Food retention factor file – information on the recipe factors

Food measures database – 16,152 measures for the 5,740 foods and beverages

Dietary supplement details file – descriptive information on 2,163 dietary supplements

Dietary supplement nutrient database – 35 nutrient values for each of the 2,163 dietary supplements

Dietary supplement recipe file – ingredient information on 18 dietary supplement recipes

Food and dietary supplement classification system

1995 NNS and 2011–13 AHS food classification concordance file

AUSNUT 2011–13 – AUSNUT 1999 Matching File

To apply NOVA system into the 2011-13 AUSNUT dataset, we used the following files: a) Food details file, b) Food composition database, c) Food recipe file.

[3]FSANZ. Food Standards Australia New Zealand, 2014. AUSNUT 2011-2013 - Food Composition Database. Available at: <http://www.foodstandards.gov.au/ science/monitoringnutrients/ausnut/pages/default.aspx>.

2 Applying the NOVA system to the 2011-13 AUSNUT database

1st step: Identifying handmade recipes

We first combined the ‘Food recipe file’ with the ‘Food composition database’. We also used the food name to identify handmade recipes. We identified 10 different sources of foods, which are presented below, including the decision about the disaggregation.

Food source		Examples	Decision
1	Homemade	13404004 Quiche, Lorraine, homemade	Apply recipe – disaggregate
2	Commercial	13101004 Biscuit, sweet, chocolate flavoured, commercial	Packaged foods do not disaggregate
		24904030 Salad, tabouleh, commercial	Potentially made from a commercial kitchen/ restaurant, disaggregate
3	Fast food	13505004 Chicken burger, white roll, chicken breast, with bacon, cheese, egg & sauce, fast food chain-style	Do not disaggregate
4	Takeaway	13503048 Kebab wrap, falafel, with salad & sauce, takeaway	Apply recipe – disaggregate
5	Purchased frozen	13502003 Pizza, cheese & tomato, purchased frozen, baked	Do not disaggregate
6	Ready to eat	13405008 Pastry, filled with spinach, commercial, ready to eat	Do not disaggregate
7	I or restaurant	21602001 Soup, lentil or other legumes, from I or restaurant	Apply recipe – disaggregate
8	Dry (powder):	21201008 Soup, pea & ham, cup of soup, instant dry mix	Apply recipe – disaggregate (considering reconstitution)
9	Canned/ Preserved	24501006 Pea, green, canned in brine, cooked	Do not disaggregate
0	Unspecified	19401017 Cheese, haloumi	Packaged products do not disaggregate
		11202003 Coffee, cappuccino, from ground coffee beans, with regular fat cows milk	Potentially handmade, disaggregate

A total of 2,585 (45%) food codes were subject to disaggregation and this process was continued until all ingredients were single food items. For food codes with no recipe in the AUSNUT Food recipe file, we applied recipes of similar foods. The cases and the recipes applied to these foods is presented below.

Food code	Food description	Recipe used to replace
31304004	Stock, liquid, fish, homemade from basic ingredients	*Food code:* 31304003 Stock, liquid, fish, commercial *Ingredients:* 11701005 Water, tap 15101118 Fish, white flesh, raw, not further defined 31301007 Salt, table, non-iodised 11301015 Juice, lemon, commercial 27101006 Sugar, white, granulated or lump 24802009 Onion, mature, brown skinned, peeled, raw 31302017 Pepper, ground, black or white 29202005 Wine, white, cooked
31304002	Stock, liquid, all flavours (except fish), homemade from basic ingredients	There is no similar recipe (only with fish as mentioned before. We applied the previous recipe: *Food code:* 31304003 Stock, liquid, fish, commercial.
21102004	Soup, minestrone, prepared, from I or restaurant	*Food code*: 21102008 Soup, mixed vegetable & legume, with pasta or grains, prepared with stock or water, homemade from basic ingredients *Ingredients:* 24802013 Onion, mature, peeled, fresh or frozen, baked, roasted, 24802002 Garlic, peeled or unpeeled, fresh or frozen, baked, roas 24101049 Potato, peeled, raw, not further defined 24701013 Pumpkin, peeled, fresh or frozen, raw 24301005 Carrot, mature, peeled or unpeeled, fresh or frozen, raw 24702007 Zucchini, green skin, fresh or frozen, peeled or unpeele 24502005 Bean, green, fresh or frozen, raw 24602006 Tomato, whole, canned in tomato juice, undrained 31304001 Stock, liquid, all flavours (except fish), prepared from c 24401013 Spinach, fresh, raw 24403006 Herbs, mixed, raw 14602003 Fat or oil, not further defined, for use in home cooked r 31302017 Pepper, ground, black or white 12101013 Grains & pasta, for homemade soup recipes 25101020 Legumes, mixed, for use in homemade soup recipes
18701014	Curry, commercial, beef, vindaloo sauce	*Food code*: 18701013 Curry, commercial, beef, tomato based sauce *Ingredients:* 18101025 Beef, casserole cuts, fully-trimmed, boiled, casseroled, 24802019 Onion, mature, peeled, fresh or frozen, boiled, microwa 24802003 Garlic, peeled or unpeeled, fresh or frozen, boiled, micr 24302021 Ginger, peeled, fresh or frozen, boiled, microwaved or 14403001 Oil, not further defined 24602008 Tomato, whole, canned in tomato juice, boiled or micro 23109002 Paste, curry, Indian style, commercial 31301007 Salt, table, non-iodised 14102001 Ghee, clarified butter 24803021 Mixed vegetables, cooked, for use in all other curry rec

Food code	Food description	Recipe used to replace	
18705007	Curry, commercial, lamb, dairy based sauce	*Food code*: 18705009 Curry, commercial, lamb & vegetable, dairy based sauce	
		Ingredients:	
		24802019	Onion, mature, peeled, fresh or frozen, boiled, microwa
		24802003	Garlic, peeled or unpeeled, fresh or frozen, boiled, mic
		24302021	Ginger, peeled, fresh or frozen, boiled, microwaved or
		14403001	Oil, not further defined
		24602008	Tomato, whole, canned in tomato juice, boiled or micro
		19201004	Yoghurt, natural, regular fat (~4%)
		22204006	Nut, almond, without skin, blanched, unsalted
		23109002	Paste, curry, Indian style, commercial
		14102001	Ghee, clarified butter
		18102013	Lamb, casserole cuts, semi-trimmed, boiled, casseroled
		31301007	Salt, table, non-iodised
		24803021	Mixed vegetables, cooked, for use in all other curry rec
18705020	Tandoori lamb, omercial	*Food code*: 18901031 Tandoori chicken, homemade, with commercial paste & yoghurt	
		Ingredients:	
		18301030	Chicken, fillet or kebab, flesh, raw
		23109002	Paste, curry, Indian style, commercial
		19201002	Yoghurt, Greek style (~8%), natural
		24802002	Garlic, peeled or unpeeled, fresh or frozen, baked, roast
		11302004	Juice, lemon, home squeezed
		14403001	Oil, not further defined
		24802012	Onion, mature, peeled, fresh or frozen, raw, not further

2st step: Applying NOVA system into food codes or underlying ingredients after full disaggregation

Two experts with Australian food and dietary intake knowledge applied the NOVA system to the AUSNUT 2011-13. All classifications were checked by another two independent food assessment experts and where classification discrepancies arose, these were discussed until consensus was reached amongst all researchers. We applied NOVA system in the ingredient fully disaggregated level, considering:

a) The AUSNUT classification system that considers a major (two-digit), sub-major (three-digit), minor (five-digit) food group or the survey ID (eight-digit). For instance, the sub-major (three-digit) was used to classify all soft drinks (e.g. 115 – Soft drinks, and flavoured mineral waters) in the ultra-processed food group. The minor (five-digit) was used to classify preserved fruits (e.g. 16104 –Pears, commercially sterile) in the processed food group, while the survey ID (eight-digit) was used to identify exceptions (e.g. 16104011 Pear, canned in intense sweetened liquid, drained – classified as ultra-processed food)

b) The source of food, for non-disaggregated food codes. All fast foods and meals purchased frozen were classified in the ultra-processed food groups, and most of the canned/preserved foods were classified in the processed food group
c) Information present in the list of ingredients of food items sold in the Australian supermarkets websites (Coles and Woolworths). These supermarket chains hold a 70% of market share in Australia (Roy Morgan Research, 2017[4])
d) Previous publication applying the NOVA system into non-disaggregated AUSNUT 2011-13 (O'Halloran et al., 2017[5])

When the classification of a food item was not clear (e.g. cake or cupcake, honey, commercial or homemade), the conservative alternative was chosen (homemade in this case, and thus disaggregated).

Breads, frequently consumed by the Australian population, may be either processed or ultra-processed foods. We first identified the processed breads, and these included: focaccia, ciabatta, baguette, pane di casa, sour dough, flats (naan, paratha, chapatti, roti, injera, and pita), pumpkin bread, corn bread and tortillas. The ultra-processed breads identified were: bagel, breadcrumbs, hot dog breads, fast food breads, pizza bases, all light breads and with addition of fibre, vitamins and minerals.

Of the 62 generic bread codes where the NOVA classification was not easily apparent, there were two generic bread codes that contributed the most to total bread energy intake (25% combined): i) Bread, from white flour, commercial, ii) Bread roll, from white flour, commercial. According to the AUSNUT 'Food details file', for the first bread code (i), proximates, vitamins, minerals, and fatty acids were derived from of *8 samples of Bakers Delight white bread purchased nationally in 2008 (2008 KFP) and a composite or individual analysis of 10 purchases of 6 brands (4x Mighty Soft, 2x Helgas, 1x Sunblest, 1x Foodland, 1x Super Soft, 1x Master White) of white*

[4]Roy Morgan Research, 2017. Aldi hits new high in supermarket wars. Available at: *http://www.roymorgan.com/findings/7234-woolworths-coles-aldi-iga-supermarket-market-shares-australia-march-2017-201705171406*

[5]O'Halloran, S.A.; Lacy, K.E.; Grimes, C.A.; Woods, J.; Campbell, K.J.; Nowson, C.A. A novel processed food classification system applied to Australian food composition databases. *Journal of Human Nutrition and Dietetics*, 2017.

bread purchased nationally in each state and territory capital city and two regional centres in NSW and QLD (2006 – KFP). As the samples were mostly of mass-produced branded breads, based on observation of bread types across a range of supermarkets websites and other retailers in Melbourne, this bread code was classified as ultra-processed. For the second bread code (ii), *the majority of nutrient data including minerals, moisture, fibre, protein, starch, B1, B3 and pantothenate were derived from individual analysis of 10 purchases of 5 brands of bread rolls (4x Coles, 2x Woolworths, 2x TipTop, 1x IGA, 1x local bakery) purchased nationally in each state and territory capital city and 2 regional centres in NSW and QLD (2006 – KFP). Fat, ash, sugars, tryptophan and vitamins were determined in a composite of the 10 purchases in the same program*. As the samples were mostly of simple unpackaged breads, based on observation of bread types across Coles and Woolworths supermarkets in Melbourne, this bread code was classified as processed bread. All the remaining breads were classified as processed breads as the conservative approach.

The final application of NOVA system to the groups and subgroups of the 2011-13 AUSNUT dataset is presented further in the document *Food Group Code Classified* (Appendix 3). The groups and subgroups of NOVA food classification system applied to the AUSNUT 2011-13 is presented below. For the analyses, we aggregated the following subgroups:

Red meat and poultry: Red meat (subgroup 4) + Poultry (5)
Fruits: Fruits (2) + Freshly squeezed juices (47)
Frozen and shelf stable ready meals: Packaged ready meals (26) + Industrial French fries (33) + Frozen pizza (38) + Instant and canned soups (40)
Pastries, buns, and cakes: Pastries, buns, and cakes (32) + Industrial desserts (39)
Other ultra-processed foods: Other ultra-processed foods (45) + Ultra-processed cheese (44)

Groups and subgroups of NOVA food classification system applied to the AUSNUT 2011-13/ NNPAS 2011-12

Group	Subgroup	
1		**Unprocessed or minimally processed foods**
	1	Milk and plain yoghurt
	2	Fruits
	3	Potatoes and other tubers and roots
	4	Red meat
	5	Poultry
	6	Cereals
	7	Pasta
	8	Vegetables
	9	Eggs
	10	Nuts and seeds
	11	Fish
	12	Legumes
	13	Other unprocessed or minimally processed foods[a]
	47	Freshly squeezed juices
2		**Processed culinary ingredients**
	14	Salt
	15	Table sugar
	16	Animal fats
	17	Plant oil
	18	Other processed culinary ingredients[b]
3		**Processed foods**
	19	Beer and wine
	20	Cheese
	21	Vegetables and other plant foods preserved in brine
	22	Processed breads
	23	Bacon and other salted, smoked or canned meat or fish
	24	Other processed foods[c]
4		**Ultra-processed foods**
	25	Mass-produced packaged breads
	26	Packaged ready meals
	27	Breakfast cereals
	28	Sausage and other reconstituted meat products
	29	Confectionary
	30	Ice cream, ice pops and frozen yogurts
	31	Biscuits
	32	Pastries, buns, and cakes
	33	Industrial French fries
	34	Margarine and other spreads
	35	Milk-based drinks
	36	Sauces, dressing and gravies
	37	Packaged salty snacks
	38	Frozen pizza
	39	Industrial desserts
	40	Instant and canned soups
	41	Soft drinks, carbonated
	42	Fruit drinks and iced teas
	43	Alcoholic distilled drinks
	44	Ultra-processed cheese
	45	Other ultra-processed foods[d]
	46	Fast food dishes

a Including non presweetened, non-flavored coffee and tea; coconut water; b Including vinegar; baking powder and baking soda; c Including salted or sugared nuts and seeds; peanut, sesame, cashew; d Including soya products such as meatless patties and fish sticks; baby food and baby formula.

Appendix 2. Example of routine of the application of NOVA system into the disaggregated items of the 2011-13 AUSNUT database (for use in Stata software – full routine available online)

```
tostring ingcode, replace
gen digcode3_ing = substr(ingcode, 1, 3)
gen digcode5_ing = substr(ingcode, 1, 5)
destring ingcode digcode3_ing digcode5_ing, replace
gen nova_group = .
gen subgroups = .

 ********************************************************************************
 *          11          Non-alcoholic beverages
 ********************************************************************************
 *          111         Tea
*           11101       Tea, regular, caffeinated, prepared with water
replace nova_group = 1 if digcode5_ing == 11101
replace subgroups = 13 if digcode5_ing == 11101
*           11102       Tea, regular, caffeinated, prepared with milk or milk substitute
replace nova_group = 1 if digcode5_ing == 11102
replace subgroups = 13 if digcode5_ing == 11102
*           11103       Tea, regular, decaffeinated, prepared with water or milk
replace nova_group = 1 if digcode5_ing == 11103
replace subgroups = 13 if digcode5_ing == 11103
*           11104       Tea mixed with other foods
replace nova_group = 4 if digcode5_ing == 11104
replace subgroups = 42 if digcode5_ing == 11104
*           11105       Herbal tea
replace nova_group = 1 if digcode5_ing == 11105
replace subgroups = 13 if digcode5_ing == 11105
*           11106       Tea powders and bases
replace nova_group = 4 if digcode5_ing == 11106
replace subgroups = 42 if digcode5_ing == 11106
*           112         Coffee and coffee substitutes
*           11201       Coffee beverage, prepared with water
replace nova_group = 1 if digcode5_ing == 11201
replace subgroups = 13 if digcode5_ing == 11201
*           11202       Coffee beverage, prepared with milk or milk substitute
replace nova_group = 1 if digcode5_ing == 11202
replace subgroups = 13 if digcode5_ing == 11202
*           11203       Coffee beverage, decaffeinated, prepared with water
replace nova_group = 1 if digcode5_ing == 11203
replace subgroups = 13 if digcode5_ing == 11203
*           11204       Coffee beverage, decaffeinated, prepared with milk or milk substitute
replace nova_group = 1 if digcode5_ing == 11204
replace subgroups = 13 if digcode5_ing == 11204
*           11205       Dry coffee powder, caffeinated or decaffeinated
replace nova_group = 1 if digcode5_ing == 11205
replace subgroups = 13 if digcode5_ing == 11205
*           11206       Coffee substitutes, beverage
replace nova_group = 4 if digcode5_ing == 11206
replace subgroups = 42 if digcode5_ing == 11206
*           11207       Coffee substitutes, powders and bases
replace nova_group = 4 if digcode5_ing == 11207
replace subgroups = 42 if digcode5_ing == 11207
*           11208       Coffee-based mixes, beverage
replace nova_group = 4 if digcode5_ing == 11208
replace subgroups = 42 if digcode5_ing == 11208
*           11209       Dry or concentrate coffee-based mixes
replace nova_group = 4 if digcode5_ing == 11209
replace subgroups = 42 if digcode5_ing == 11209
*           113         Fruit and vegetable juices, and drinks
*           11301       Fruit juices, commercially prepared
replace nova_group = 4 if digcode5_ing == 11301
replace subgroups = 42 if digcode5_ing == 11301
*           11302       Fruit juices, freshly-squeezed
replace nova_group = 1 if digcode5_ing == 11302
replace subgroups = 47 if digcode5_ing == 11302
*           11303       Fruit juices, fortified
replace nova_group = 4 if digcode5_ing == 11303
replace subgroups = 42 if digcode5_ing == 11303
*           11304       Vegetable juices
replace nova_group = 4 if digcode5_ing == 11304
replace subgroups = 42 if digcode5_ing == 11304
            *Excpetion (aloe vera, carrot and celery)
replace nova_group = 1 if (ingcode == 11304001 | ingcode == 11304002 | ingcode == 11304003)
replace subgroups = 47 if (ingcode == 11304001 | ingcode == 11304002 | ingcode == 11304003)
*           11305       Vegetable juices, freshly squeezed
replace nova_group = 1 if digcode5_ing == 11305
replace subgroups = 47 if digcode5_ing == 11305
*           11306       Fruit and vegetable juice blends
replace nova_group = 4 if digcode5_ing == 11306
replace subgroups = 42 if digcode5_ing == 11306
```

Appendix 3. Sensitivity analyses to account for exposure misclassification of breads

Table S1. Average nutrient content of the overall diet and of two diet fractions. Australian population aged 2+ years (NNPAS 2011–2012) (n = 12,153)[¥].

Nutrients	Overall diet		Ultra-processed food diet fraction		Non-ultra-processed food diet fraction[a]	
	Mean	(SE)	Mean	(SE)	Mean	(SE)
Free sugars (% of total energy)	11.7	(0.1)	24.3	(0.2)	4.2*	(0.1)
Total fats (% of total energy)	31.1	(0.1)	35.3	(0.2)	28.7*	(0.1)
Saturated fat (% of total energy)	12.0	(0.1)	14.1	(0.1)	10.6*	(0.1)
Trans fat (% of total energy)	0.6	(0.0)	0.6	(0.0)	0.6	(0.0)
Dietary fibre (g/1,000 kcal)	11.5	(0.1)	8.9	(0.1)	13.3*	(0.1)
Sodium (mg/1,000 kcal)	1213	(6.4)	2414	(96.5)	986*	(6.7)
Potassium (mg/1,000 kcal)	1444	(6.6)	1125	(10.9)	1695*	(8.8)
Energy density (kcal/g)[b]	1.7	(0.0)	2.7	(0.0)	1.5*	(0.0)

SE: Standard Error

[¥]Analyses considering 11.6% of total energy intake from processed breads (20.6% of total energy intake from processed foods, 37.2% of total energy intake from ultra-processed foods).

[a]It includes NOVA unprocessed or minimally processed foods, processed culinary ingredients and processed foods.

[b]Beverages excluded.

*p<0.001 for significant mean differences between the two fractions of the diet.

Table S2. Average nutrient content of the overall diet according to quintiles of the dietary share of ultra-processed foods. Australian population aged 2+ years (NNPAS 2011–2012) (n = 12,153)[¥].

Nutrients	Quintiles of the dietary contribution of ultra-processed foods (% of total dietary energy)[a]					Standardized regression coefficients[b]	
	Q1	Q2	Q3	Q4	Q5	Crude	Adjusted†
Free sugars (% of total energy)	5.5	8.9	11.5	14.5	17.9	0.48*	0.46*
Total fats (% of total energy)	29.9	30.4	30.8	31.4	32.7	0.10*	0.10*
Saturated fat (% of total energy)	10.3	11.2	12.1	12.7	13.5	0.24*	0.21*
Trans fat (% of total energy)	0.52	0.56	0.59	0.63	0.65	0.12*	0.11*
Dietary fibre (g/1,000 kcal)	13.4	12.3	11.5	11.0	9.3	-0.25*	-0.22*
Sodium (mg/1,000 kcal)	1080	1160	1212	1280	1338	0.17*	0.17*
Potassium (mg/1,000 kcal)	1654	1534	1463	1388	1181	-0.28*	-0.24*
Energy density (kcal/g)[c]	1.5	1.6	1.7	1.8	2.1	0.40*	0.38*

[¥]Analyses considering 11.6% of total energy intake from processed breads (20.6% of total energy intake from processed foods, 37.2% of total energy intake from ultra-processed foods).
[a]Percentage of total energy intake from ultra-processed foods. Mean (range): Q1= 9.6 (0 to 17.6); Q2= 23.6 (17.6 to 29.3); Q3= 35.2 (29.3 to 41.4); Q4= 48.2 (41.4 to 56.3); Q5= 69.5 (56.3 to 100).
[b]Obtained with linear regression of the dietary nutrient content on the quintiles of the dietary share of ultra-processed foods, and expressed in standard deviation units.
[c]Beverages excluded.
†Adjusted for age, sex, educational attainment, socio-economic status and geographical location.
*Statistically significant $p<0{\cdot}001$

Table S3. Prevalence (%) of non-recommended nutrient intake levels according to quintiles of the dietary share of ultra-processed foods Australian population aged 2+ years (NNPAS 2011–2012) (n = 12,153)[¥].

Quintiles of the dietary contribution of ultra-processed foods (% of total dietary energy)[a]	Non-recommended nutrient intake levels of:															
	Free sugars		**Total fat**		**Saturated fat**		**Trans fat**		**Dietary fibre**		**Sodium**		**Potassium**		**Energy density**	
	≥10% of energy		≥30% of energy		≥10% of energy		≥1% of energy		≤12.5g/ 1,000 kcal		≥1,000 mg/ 1,000 kcal		≤1,755mg/ 1,000 kcal		≥2.25kcal/g	
	%	PR	%	PR	%	PR	%	PR	%	PR	%	PR	%	PR	%	PR
Q1 (lowest)	21.1	1.0	51.8	1.0	56.2	1.0	5.8	1.0	55.6	1.0	68.9	1.0	75.4	1.0	2.2	1.0
Q2	45.7	2.1	53.0	1.0	68.7	1.2	4.3	0.8	64.2	1.1	75.7	1.1	83.3	1.1	2.8	1.2
Q3	58.1	2.7	60.7	1.2	76.5	1.3	7.4	1.3	70.5	1.2	80.7	1.2	87.9	1.1	4.6	2.0
Q4	71.6	3.3	65.4	1.2	82.4	1.4	7.5	1.3	75.7	1.3	79.8	1.2	89.9	1.2	8.9	3.4
Q5 (highest)	83.0	3.8‡†	69.1	1.3‡†	85.1	1.5‡†	10.7	1.9‡†	84.9	1.5‡†	84.2	1.2‡†	94.1	1.2‡†	22.7	9.2‡†
Total	55.9	-	60.0	-	73.8	-	7.2	-	70.2	-	77.9	-	86.1	-	8.3	-

[¥]Analyses considering 11.6% of total energy intake from processed breads (20.6% of total energy intake from processed foods, 37.2% of total energy intake from ultra-processed foods).
PR: Prevalence ratios adjusted for age, sex, educational attainment, socio-economic status and geographical location.
[a]The same as the previous table.
‡ Significant linear trend across quintiles (p<0.001) in both unadjusted (coefficients not shown) and adjusted models.
[†] Wald test at 5% significance level.

4 ASSOCIAÇÃO ENTRE O CONSUMO DE ALIMENTOS ULTRAPROCESSADOS E A INGESTÃO DE AÇÚCARES LIVRES EM DIFERENTES GRUPOS ETÁRIOS NA AUSTRÁLIA

Este capítulo apresenta o artigo "*Ultra-processed food consumption drives excessive free sugars intake among all age groups in Australia*" de autoria de Priscila Pereira Machado, Eurídice Martinez Steele, Maria Laura da Costa Louzada, Renata Bertazzi Levy, Anna Rangan, Julie Woods, Timothy Gill, Gyorgy Scrinis, e Carlos Augusto Monteiro. O artigo foi submetido para publicação na revista *European Journal of Nutrition* e encontra-se em fase de revisão (comprovante em anexo).

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Ultra-processed food consumption drives excessive free sugars intake among all age groups in Australia

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ABSTRACT

Objective: To analyse the contribution of ultra-processed foods to the intake of free sugars among different age groups in Australia. **Methods:** Dietary intakes of 12,153 participants from the National Nutrition and Physical Activity Survey (2011-12) aged 2+ years were evaluated. Food items collected through two 24-hour recalls were classified according to the NOVA system. The contribution of each NOVA food group and their subgroups to total energy intake was determined by age group. Mean free sugars content in diet fractions made up exclusively of ultra-processed foods, or of processed foods, or of a combination of un/minimally processed foods and culinary ingredients (which includes table sugar and honey) were compared. Across quintiles of the energy contribution of ultra-processed foods, differences in the intake of free sugars, as well as in the prevalence of excessive free sugars intake (≥10% of total energy) were examined. **Results:** Ultra-processed foods had the highest energy contribution among children, adolescents and adults in Australia, with older children and adolescents the highest consumers (53.1% and 54.3% of total energy, respectively). The diet fraction restricted to ultra-processed items contained significantly more free sugars than the two other diet fractions. Among all age groups, a positive and statistically significant linear association was found between quintiles of ultra-processed food consumption and both the average intake of free sugars and the prevalence of excessive free sugars intake. **Conclusion:** Ultra-processed food consumption drives excessive free sugars intake among all age groups in Australia.

Keywords: Food processing; Ultra-processed food; Free sugar; Diet quality; Australia

Conflict of interest

The authors declare that they have no conflict of interest.

4.1 INTRODUCTION

Free sugars are defined by the World Health Organization (WHO) as monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer (added sugars), and those naturally present in honey, syrups and fruit juices [1]. Excessive consumption of free sugars increases the risk of unhealthy weight gain and dental caries [2-4] and, for this reason, the WHO recommends reducing the consumption of free sugars to less than 10% of total energy intake [1].

There is evidence that the consumption of ultra-processed foods drives excessive free or added sugars intake in the U.S. [5], the U.K. [6], Canada [7], Chile [8], Colombia [9] and Brazil [10]. Ultra-processed foods are defined by the NOVA food classification system as industrial formulations manufactured from substances derived from foods with little if any whole food and typically added of flavors, colors and other cosmetic additives [11]. Sucrose extracted from sugar cane or beet, fruit juice concentrates and other free sugars obtained by chemical synthesis, such as high fructose corn syrup and invert sugar, are common ingredients of ultra-processed foods [11].

In 2012, data from the FoodSwitch branded food composition database showed that 70% of packaged foods in the Australian food supply contained added sugars [12]. In the same period, Australians consumed an average of 11% of their dietary energy intake from free sugars, with children and adolescents more likely to exceed the recommended 10% cut-off [13]. Sugar-sweetened beverages (SSBs) were the major source of free sugars in the Australian diet [13, 14] but the contribution of the entire NOVA group of ultra-processed foods has not yet been studied. The objective of the present study was to analyse the contribution of ultra-processed foods to the intake of free sugars among different age groups in Australia.

4.2 METHODS

Data source and collection

The data source for this study was the National Nutrition and Physical Activity Survey (NNPAS) 2011-12, part of the 2011-13 Australian Health Survey. This survey studied a randomly selected, national sample of the Australian population using a complex, stratified, multistage probability cluster sampling design with selection of strata, households and people within households. The NNPAS was conducted between May 2011 and June 2012 on 9,519 households where 12,153 Australians aged 2 years and above were interviewed [15].

Data on food intake were collected as part of NNPAS based on two 24-hour dietary recalls administered by trained and experienced interviewers using the Automated Multiple-Pass Method. The first recall was applied through a face-to-face interview (n=12,153) while the second recall (n=7,735) was applied via a telephone interview conducted 8 days or more after the first interview, preferably in a different day of the week [15]. Under 9 years of age, parents/guardians were used as proxies. Energy and free sugars intakes were estimated based on the Australian Food and Nutrient Database (AUSNUT 2011-13), which contains information for 5,740 foods and beverages consumed during the survey [16].

Questions on socio-economic characteristics were collected for participants over 15 years of age, or their proxies otherwise. Information included sex, age, socio-economic status (assessed with the Socio-Economic Index of Disadvantage for Areas – SEIFA, a ranking based on the relative socio-economic advantage and disadvantage of the location of the household), educational attainment and geographical location (urbanity of the household location based on the Australian Standard Geographical Classification remoteness classification) [15].

Food classification

Mixed dishes composed of two or more food items were disaggregated using the AUSNUT 2011-2013 Food Recipe File (45% of food codes). Reported single food items and the underlying ingredients of mixed dishes were classified according to the NOVA food classification system into the following four groups (and subgroups within these groups):

Group 1 - Unprocessed or minimally processed foods (e.g. rice and other cereals, meat, fish, milk, eggs, fruit, roots and tubers, vegetables, nuts and seeds); Group 2 - Processed culinary ingredients (e.g. sugar, plant oils and butter); Group 3 - Processed foods (e.g. processed breads and cheese, canned fruit and fish, and salted and smoked meats); Group 4 - Ultra-processed foods (e.g. confectionaries, savoury snacks, fast food dishes, mass-produced packaged breads, frozen and ready meals, fruit drinks and soft drinks) [11].

Food items were ultimately classified as ultra-processed if they contained ingredients not (or rarely) used in household kitchens, i.e. substances derived from (e.g.: invert sugar, protein isolates, modified starches, hydrogenated oils), and classes of additives with cosmetic functions (e.g.: colorants, flavourings, artificial sweeteners, emulsifiers, thickeners, and bleaching, bulking, firming, gelling, glazing, foaming, and carbonating agents) [11].

To classify all food items, two experts with Australian food and dietary intake knowledge applied the NOVA system to the AUSNUT 2011-13. All classifications were checked by another two independent food assessment experts and where classification discrepancies arose, these were discussed until consensus was reached amongst all researchers. The conservative alternative was chosen (non-ultra-processed food) when the classification of a food item was not clear (e.g. cake or cupcake, honey, commercial or homemade). More information regarding how to identify ultra-processed foods can be found elsewhere [11].

Data analysis

The mean daily contribution of each NOVA food group and their subgroups to the total energy intake for the total population and by age strata (2-5 years; 6-11 y; 12-19 y; 20-64 y; ≥65 y), was determined. Then, the mean free sugars content (% of total energy from free sugars) in the Australian diet and in three fractions of this diet: a combination of unprocessed or minimally processed foods and processed culinary ingredients, as they are usually consumed together; processed foods; and ultra-processed foods, were calculated. Differences between the ultra-processed foods fraction and each of the other fractions of the diet were analysed using tests of means for independent samples (t-test).

The population was stratified into quintiles of the energy share of ultra-processed foods and the mean content of free sugars in the overall diet was then estimated across those quintiles.

Adjusted linear regression models were used to assess the direction, strength and the statistical significance of the association of those quintiles (treated as ordinal score) with free sugars intake. For these analyses, the first 24-hour recall was used.

Finally, the prevalence of excessive free sugars intake (≥10% of total energy) [1], for the overall population and for quintiles of the dietary share of ultra-processed foods, was estimated. For this analysis, intakes were adjusted by the Multiple Source Method (MSM) to account for intra-person variability by considering the data from the second 24-h recall, which is the recommended approach to evaluate dietary adequacy [17]. Prevalence ratios from Poisson regression models were used to assess the magnitude of the associations between quintiles of energy contribution of ultra-processed foods and excessive free sugars intake. Wald tests were used to compare prevalence of excessive intake between extreme quintiles. Tests of linear trend were also performed treating quintiles as an ordinal variable.

All regression models were adjusted for sex (male/female), age (continuous), Socio-Economic Index of Disadvantage for Areas (SEIFA – quintiles), educational attainment of respondents, for participants ≥18 years old, and of household reference persons otherwise (completed 9 years or below including never attended, completed 10 to 12 years with no graduate degree, completed 12 years with graduate degree), and geographical location (major cities of Australia, inner regional, and other, which includes outer regional, remote and very remote Australia).

Weighted analyses were performed using Stata survey module (version 14) to consider the effect of complex sampling procedures adopted in the NNPAS 2011-12 and in order to allow extrapolation of results for the Australian population (Stata Corp., College Station, United States).

This study was a secondary analysis using de-identified data from the ABS Basic Confidentialised Unit Record Files (CURFs), and permission to use the data was obtained. Ethics approval for the survey was granted by the Australian Government Department of Health and Ageing Departmental Ethnics Committee in 2011 [15].

4.3 RESULTS

Table 1 describes the mean contribution of each NOVA food group and their subgroups to total daily energy intake for the total population and by age groups in Australia. Ultra-processed foods, the focus of this study, had the highest dietary energy contribution (42.0% of energy intake), ranging from 36.3% of total energy intake among the elderly and 54.3% in adolescents. For the whole population, the three ultra-processed food types with the highest energy share were packaged breads, ready meals and fast food dishes. Packaged breads were among this group of ultra-processed foods for all age groups, ready meals were so for older children, adolescents and adults and fast food dishes for adolescents and adults. Biscuits made the highest contribution to energy intake of all ultra-processed foods among young and older children, with fruit drinks and iced teas being in the top three energy contributors for young children. Pastries, buns and cakes and breakfast cereals were the highest contributors of energy from ultra-processed foods among the elderly.

Table 2 shows the mean dietary content of free sugars in the overall diet and in selected diet fractions. Free sugars represented 11.7% of the energy intake in the overall Australian diet, ranging from 10.0% among the elderly to 15.0% in adolescents. The diet fraction made up exclusively of ultra-processed items contained significantly more free sugars (four times) than the fraction made up of unprocessed or minimally processed foods and culinary ingredients (which includes table sugar and honey), and five times more than the fraction made up exclusively of processed foods. These differences are even higher for older children and adolescents, for whom the ultra-processed fraction of the diet has seven times more free sugars than the two other diet fractions. The main sources of free sugars within ultra-processed foods, overall and among each age group, can be seen in Table S1.

Table 3 presents the mean dietary content of free sugars in the overall diet across quintiles of ultra-processed food intake. Adjusted regression coefficients show a direct and statistically significant linear trend between the dietary share of ultra-processed foods and the mean percentage of energy intake from free sugars for all age groups. The mean free sugars intake at least doubled between extreme quintiles of ultra-processed food consumption, and only

Australians in the lowest quintile of ultra-processed food consumption met the recommended limit of <10% energy from free sugars.

Table 4 shows the prevalence of excessive free sugars intake across quintiles of the dietary energy share of ultra-processed foods. In the highest quintile of ultra-processed food consumption, 82.1% of the Australian population exceeded the upper limit recommended for free sugars (while 21.7% exceeded in the lowest quintile), and this was even higher for older children (48.7% *vs* 91.6%) and adolescents (52.4% *vs* 89.0%). The prevalence of excessive free sugars intake increased linearly across quintiles of the dietary share of ultra-processed foods for all age groups. A notable increase between extreme quintiles was observed for young children (Pradj 3.6, $p<0.001$), adults (Pradj 3.9, $p<0.001$), and the elderly (Pradj 3.4, $p<0.001$).

4.4 DISCUSSION

This study presents data on the dietary contribution of ultra-processed foods to the intake of free sugars for different age groups in Australia using data from the most recent national nutrition survey. Until now, Australian studies on added or free sugars intake have focused only on specific types of foods and subgroups [14, 18], without considering the role of processing, and, in particular, ultra-processing. The results indicate that the broader category of ultra-processed foods drives the excessive free sugars intake in Australia. This is of concern when considering the overwhelming evidence on the negative effects of sugar on human metabolic health [1-4, 19] and the increasing consumption of ultra-processed foods in Australia [20].

The energy contribution from ultra-processed foods was high among all age groups in Australia, with older children and adolescents consuming more than 50% of all calories from ultra-processed foods. Although previous studies have already shown a high consumption of fast foods and SSBs among Australian children and adolescents [14, 18], few studies worldwide have explored the contribution of all ultra-processed foods to the children's diets

[8, 21, 22]. The dietary share of ultra-processed foods has been considered a key metric to evaluate dietary patterns and an effective predictor of the nutritional quality of diets [23, 24].

A strong linear relationship was found in the association between the energy contribution of ultra-processed and that of free sugars among all age groups in Australia. Studies spanning multiple high and middle-income countries have found similar results [5-10], despite differences in the average dietary share of ultra-processed foods. In Australia, ultra-processed foods accounted for 74% of the energy from free sugars, almost twice the contribution of ultra-processed foods to total energy intake (42%). This is a consequence of the high content of free sugars in the diet fraction made up of ultra-processed foods, far higher than the same content in the diet fraction made up of unprocessed or minimally processed foods plus processed culinary ingredients (mostly from table sugar) or in the diet fraction made up of processed foods. For older children and adolescents, ultra-processed foods provided almost 90% of total free sugars intake, particularly from SSBs, which may add to total energy intake without displacing energy consumed in the form of solid food, contributing to higher risk of weight gain and NCDs already in childhood [1, 2].

The extremely high average content of free sugars in ultra-processed food items suggest that reducing the content of sugars in packaged foods through reformulation, as currently in discussion in Australia [25], while potentially useful [26], may not solve the problem of excessive free sugars intake. Reformulation policies may also drive consumers towards consuming other ultra-processed foods [27], such as those that might not be included in the national reformulation program [25], or to artificially sweetened drinks [28]. Four in five people had excessive free sugars consumption among those in the fifth quintile of ultra-processed food consumption. Interestingly, many of those in the lowest quintile of ultra-processed food consumption still exceeded the recommended free sugars intake, in particular young children (30%) and older children and adolescents (50%). This is likely due to the relatively high energy share of ultra-processed foods even among the lowest consumers. Thus, additional strategies focused on reducing ultra-processed food consumption should be considered in Australia.

Increasing decision-making power implies better access to information. Therefore, dietary guidelines and nutrition education should comprise information on the impact of food processing on human health [29]. Consumers can make healthier choices if information on food labels is clear [30], and so improving food labelling, by including information on added sugars, recently proposed in Australia [31], and warning labels [32], seems to be crucial. Evidence from Australian-based modelling [33] and international experience [34] has shown positive impact of taxation on reducing sugary drinks consumption, a strategy endorsed by the WHO [35] and strongly advocated in Australia [36]. Limiting promotion and marketing of ultra-processed foods, particularly to children, and restricting their sales in schools, health care and other settings are also recommended strategies [37].

Australians who based their diet on unprocessed and minimally processed foods, and on culinary preparations made up with these foods, are more likely to meet the WHO recommendation for free sugars intake [1]. So despite studies suggesting that the recommended cut-off is likely to be too restrictive and unachievable [14], decreasing the consumption of ultra-processed foods can be beneficial to achieve recommended free sugars intake in Australia. Moreover, evidence from experimental and large-scale observational studies reveal an association between ultra-processed food consumption and the overall quality of diet [6, 7, 9, 10], weight gain and obesity [38, 39], dyslipidaemia [40], hypertension [41], cancer [42] and overall mortality [43, 44]. This likely results from a combination of poor nutritional quality of ultra-processed foods [45], the displacement of un/minimally processed foods [23], and non-nutritional mechanisms associated with the processing itself [46], further highlighting the public health relevance of restricting the consumption of those foods.

To the best of our knowledge, this is the first study to analyze the contribution of ultra-processed foods to the intake of free sugars for different age groups in Australia. The findings were based on the most up-to-date, individual-level dietary survey data taken from a nationally representative sample of Australian children and adults, increasing generalisability. The use of the NOVA system is a key strength, as it has been considered the most specific, coherent and comprehensive food classification system based on food processing [47], as well as a relevant approach for linking dietary intakes and incidence of obesity and NCDs [29]. Use of data on free sugars, rather than total sugars, and the focus of an entire food processing group, instead of singular foods, corresponds to the relevant area of prioritisation of international guidelines [1].

This study has some limitations. Misreporting is an inherent potential bias of the 24-h recall. It can also bring challenges to assess the dietary intake among children accurately [48]. To minimize potential bias, dietary intake among children under 9 years old was reported by proxies, whose validity has been described previously [49], and children were encouraged to assist in answering the 24-hour recall questions [15]. However, since unhealthy foods are more likely to be under-reported [50], potential misreporting may lead to an underestimation of overall dietary contribution of ultra-processed foods and free sugars intake, or may attenuate the magnitude of the association found in our study (should information bias exist). On the other hand, information on table sugar was based on standard recipes [14], which may also have affected the associations. Nevertheless, the AUSNUT 2011-13 food composition database was specifically developed to reflect the food supply and food preparation practices during the period of the NNPAS 2011-12 [13, 16]. As another limitation, we cannot rule out some misclassification of food items at the individual level due to limited information indicative of food processing in both 24-h recall instrument and food composition tables. To reduce misclassification, several independent researchers reviewed the classification and any areas of misclassification were resolved by discussion and consensus.

4.5 CONCLUSION

In Australia, ultra-processed foods contribute to 42.0% of total energy intake, with older children and adolescents the highest consumers (53.1% and 54.3% of total energy, respectively). Consuming ultra-processed foods increases the overall dietary content of free sugars among all age groups in Australia, as well as the prevalence of excessive free sugars intake. Efforts on reducing free sugars intake should focus on reducing the consumption of ultra-processed foods in Australia.

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4.7 TABLES

Table 1. Distribution (%) of total daily energy intake (EI) according to NOVA food groups and subgroups, by age strata. Australian population aged 2+ years (NNPAS 2011–2012). (continues)

NOVA Food Groups	All (N=12,153) EI=1968 kcal/d	Age groups: Young children (2-5y) (N=822) EI=1446 kcal/d	Older children (6-11y) (N=889) EI=1864 kcal/d	Adolescents (12-19y) (N=1,204) EI=2107 kcal/d	Adults (20-64y) (N=7,135) EI=2051 kcal/d	Elderly (≥65y) (N=2,103) EI=1742 kcal/d
Unprocessed or minimally processed food	**35.4**	**35.3**	**29.7**	**28.8**	**36.7**	**37.9**
Red meat and poultry	8.1	4.9	5.1	7.2	8.8	8.8
Milk and plain yoghurt	6.6	11.3	7.3	5.8	6.1	6.7
Cereal grains and flours	5.9	4.7	4.8	5.0	6.5	5.0
Fruits	4.9	7.8	5.9	3.5	4.5	6.1
Vegetables	2.8	1.8	1.8	1.8	3.0	3.1
Pasta	2.3	2.0	2.2	2.8	2.4	1.4
Potatoes and other tubers and roots	1.2	0.7	1.0	0.9	1.2	1.9
Nuts and seeds	1.0	0.3	0.2	0.2	1.3	1.2
Eggs	1.0	0.7	0.8	0.7	1.1	1.3
Fish	0.8	0.4	0.3	0.4	1.0	1.2
Legumes	0.5	0.4	0.2	0.2	0.5	0.6
Freshly squeezed juices	0.03	0.05	0.04	0.00	0.03	0.03
Other[a]	0.4	0.0	0.0	0.1	0.4	0.7
Processed culinary ingredients	**6.8**	**4.5**	**4.7**	**5.3**	**7.1**	**8.1**
Plant oils	3.0	1.8	2.1	2.5	3.4	3.1
Animal fats	1.8	1.5	1.5	1.5	1.7	2.3
Table sugar	1.6	0.7	0.9	1.0	1.7	2.2
Other[b]	0.3	0.5	0.2	0.2	0.3	0.4
Unprocessed or minimally processed foods + Processed culinary ingredients	**42.2**	**39.8**	**34.4**	**34.1**	**43.8**	**46.0**
Processed foods	**15.8**	**12.9**	**12.5**	**11.6**	**16.8**	**17.7**
Processed breads	6.8	8.4	7.9	6.5	6.4	7.4
Beer and wine	3.6	0.0	0.0	0.2	4.6	4.9
Cheese	2.6	2.7	2.5	2.7	2.7	2.2
Bacon and other salted, smoked or canned meat or fish	1.2	0.4	0.7	1.0	1.3	1.2
Vegetables and other plant foods preserved in brine	0.5	0.5	0.3	0.3	0.5	0.6
Other[c]	1.2	0.8	0.9	1.0	1.3	1.3

Table 1. Distribution (%) of total daily energy intake (EI) according to NOVA food groups and subgroups, by age strata. Australian population aged 2+ years (NNPAS 2011–2012). (continuation)

NOVA Food Groups	**All (N=12,153)** EI=1968 kcal/d	Age groups: Young children (2-5y) (N=822) EI=1446 kcal/d	Older children (6-11y) (N=889) EI=1864 kcal/d	Adolescents (12-19y) (N=1,204) EI=2107 kcal/d	Adults (20-64y) (N=7,135) EI=2051 kcal/d	Elderly (≥65y) (N=2,103) EI=1742 kcal/d
Ultra-processed foods	**42.0**	**47.3**	**53.1**	**54.3**	**39.4**	**36.3**
Mass-produced packaged breads	4.8	4.3	5.2	5.1	4.6	5.5
Frozen and shelf stable ready meals[d]	3.7	3.2	4.6	4.9	3.5	3.3
Fast food dishes[e]	3.5	3.5	3.5	5.8	3.6	1.0
Pastries, buns, and cakes	3.3	3.6	4.0	3.6	3.1	3.7
Breakfast cereals	3.2	4.0	4.0	3.6	2.9	3.8
Biscuits	3.1	5.1	5.4	3.8	2.4	3.3
Fruit drinks and iced teas[f]	3.0	4.7	3.9	4.7	2.7	2.0
Confectionary	2.9	3.2	4.1	3.9	2.7	1.8
Sausage and other reconstituted meats	2.4	2.5	3.1	2.6	2.3	2.5
Milk-based drinks	2.1	3.9	2.5	2.7	2.0	1.4
Carbonated soft drinks	2.1	0.4	1.6	3.7	2.3	0.8
Sauces, dressing and gravies	1.8	1.2	1.7	2.1	1.9	1.5
Ice cream, ice pops and frozen yogurts	1.6	2.0	3.1	2.4	1.3	1.7
Salty snacks	1.6	2.6	3.5	3.2	1.2	0.5
Margarine and other spreads	1.4	1.8	1.9	1.1	1.2	2.0
Alcoholic distilled drinks	0.5	0.0	0.0	0.2	0.7	0.6
Other[g]	0.9	1.1	0.7	0.7	0.9	0.8
Total	100.0	100.0	100.0	100.0	100.0	100.0

1 kcal = 4.18 kJ
a Including meat from other animals, teas, coffees and dried spices.
b Including honey, maple syrup (100%) and vinegar.
c Including salted or sugared nuts, seeds and dried fruits.
d Including frozen lasagna, pizza and other pastas and meals, and instant soups and noodles.
e Including hamburger, pizza and French fries from fast food places.
f Including cordials, sport drinks and energy drinks.
g Including ultra-processed cheese, baby food and baby formula.

Table 2. Mean free sugars content (% of total energy) in the overall diet and in selected diet fractions, by age strata. Australian population aged 2+ years (NNPAS 2011–2012).

Diet fractions made of:	**All (N=12,153)**		Age groups: Young children (2-5y) (N=822)		Older children (6-11y) (N=889)		Adolescents (12-19y) (N=1,204)		Adults (20-64y) (N=7,135)		Elderly (≥65y) (N=2,103)	
	Mean	(SE)	Mean	(SE)	Mean	(SE)	Mean	(SE)	Mean	(SE)	Mean	(SE)
Unprocessed or minimally processed foods + Culinary ingredients	5.3*	(0.1)	3.2*	(0.3)	3.5*	(0.3)	3.9*	(0.3)	5.6*	(0.1)	6.7*	(0.3)
Processed foods	4.6*	(0.2)	5.4*	(0.9)	3.1*	(0.5)	3.4*	(0.4)	4.3*	(0.2)	7.4*	(0.5)
Ultra-processed foods	21.6	(0.2)	22.4	(0.7)	22.8	(0.5)	25.5	(0.6)	21.6	(0.3)	17.0	(0.4)
Overall diet	11.7	(0.1)	12.1	(0.4)	13.4	(0.3)	15.0	(0.3)	11.2	(0.1)	10.0	(0.2)

SE: Standard Error
*p<0.001 for significant mean differences between the ultra-processed foods fraction and each of the other two fractions.

Table 3. Mean content of free sugars (% of total energy) in the overall diet according to quintiles of the dietary share of ultra-processed foods, by age strata. Australian population aged 2+ years (NNPAS 2011–2012).

Dietary share of ultra-processed foods (quintiles)[¥]	**All (N=12,153)**		**Age groups** Young children (2-5y) (N=822)		Older children (6-11y) (N=889)		Adolescents (12-19y) (N=1,204)		Adults (20-64y) (N=7,135)		Elderly (≥65y) (N=2,103)	
	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)
Q1 (lowest)	5.8	(5.5-6.1)	7.2	(6.1-8.2)	8.5	(7.4-9.5)	9.2	(8.2-10.1)	5.5	(5.2-5.9)	5.2	(4.7-5.8)
Q2	9.2	(8.9-9.6)	10.0	(8.8-11.2)	12.0	(10.7-13.2)	13.5	(12.3-14.7)	8.3	(7.8-8.6)	8.7	(8.0-9.5)
Q3	11.7	(11.2-12.1)	11.9	(10.7-13.0)	13.4	(12.2-14.7)	14.8	(13.3-16.3)	10.9	(10.3-11.4)	10.2	(9.5-11.0)
Q4	14.0	(13.6-14.5)	14.9	(13.5-16.2)	15.9	(14.6-17.1)	17.7	(16.1-19.3)	13.9	(13.3-14.5)	11.8	(10.0-12.7)
Q5 (highest)	17.7	(17.1-18.2)	16.9	(14.8-19.1)	17.5	(16.0-19.0)	20.0	(18.4-21.6)	17.5	(16.7-18.2)	13.9	(12.8-15.1)
Adjusted regression coefficient ($\beta^{\dagger}$)	2.7*	(2.5-2.8)	2.4*	(1.9-2.9)	2.1*	(1.7-2.6)	2.5*	(2.1-2.9)	2.8*	(2.6-3.0)	2.0*	(1.7-2.3)

[¥]All: Mean (range): Q1= 12.8 (0 to 21.8); Q2= 28.4 (21.8 to 34.6); Q3= 40.4 (34.6 to 46.6); Q4= 54.1 (46.6 to 62.1); Q5= 74.5 (62.1 to 100).
Children aged 2-5y: Mean (range): Q1= 19.8 (0 to 29.6); Q2= 35.6 (29.6 to 40.7); Q3= 46.3 (40.7 to 52.2); Q4= 58.9 (52.3 to 65.8); Q5= 76.3 (65.8 to 95.3).
Children aged 6-11y: Mean (range): Q1= 26.7 (0 to 36.2); Q2= 42.4 (36.2 to 48.7); Q3= 53.8 (48.7 to 59.1), Q4= 64.6 (59.1 to 69.4); Q5= 78.6 (69.4 to 100).
Adolescents: Mean (range): Q1= 23.7 (0 to 36.0); Q2= 42.7 (36.0 to 48.5); Q3= 54.3 (48.5 to 60.0); Q4= 66.8 (60.0 to 73.2); Q5= 84.2 (73.2 to 100).
Adults: Mean (range): Q1= 11.0 (0 to 19.2); Q2= 25.6 (19.2 to 31.6); Q3= 37.3 (31.6 to 43.3); Q4= 50.7 (43.3 to 59.5); Q5= 72.5 (59.5 to 100).
Elderly: Mean (range): Q1= 11.8 (0 to 19.2); Q2= 24.5 (19.2 to 29.7); Q3= 34.5 (29.7 to 39.4); Q4= 45.9 (39.5 to 53.4); Q5= 65.0 (53.4 to 100)
[†]Obtained by regressing the dietary free sugars content on quintiles of the dietary share of ultra-processed foods with adjustment for age (continuous), sex, educational attainment, socio-economic status and geographical location.
*p for linear trend <0.001

Table 4. Prevalence (%) of individuals with excessive free sugars intake (≥10% of total energy intake) according to quintiles of the dietary share of ultra-processed foods, by age strata. Australian population aged 2+ years (NNPAS 2011–2012).

Dietary share of ultra-processed foods (quintiles)[¥]	**All** **(N=12,153)**		**Young children (2-5y)** (N=822)		**Older children (6-11y)** (N=889)		**Adolescents (12-19y)** (N=1,204)		**Adults (20-64y)** (N=7,135)		**Elderly (≥65y)** (N=2,103)	
	%	PR	%	PR	%	PR	%	PR	%	PR	%	PR
Q1 (lowest)	21.7	1.0	32.0	1.0	48.7	1.0	52.4	1.0	19.1	1.0	18.0	1.0
Q2	47.3	2.1	54.3	1.7	70.3	1.4	72.0	1.4	42.4	2.2	37.9	2.1
Q3	58.5	2.6	56.3	1.6	78.0	1.6	74.9	1.4	53.2	2.7	51.3	2.8
Q4	69.8	3.1	68.0	2.0	86.2	1.7	85.5	1.6	66.9	3.4	63.3	3.5
Q5 (highest)	82.1	3.6[‡†]	83.5	2.5[‡†]	91.6	1.9[‡†]	89.0	1.7[‡†]	78.9	3.9[‡†]	62.0	3.4[‡†]
Total	55.9	-	58.8	-	75.0	-	74.7	-	52.1	-	46.5	-

[¥] The same as the previous table.
PR: Prevalence ratios adjusted for age (continuous), sex, educational attainment, socio-economic status and geographical location.
[‡]Significant linear trend across quintiles ($p<0.001$) in both unadjusted (coefficients not shown) and adjusted models
[†]Wald test at 5% significance level

4.8 SUPPLEMENTAL FILES

Table S1. Distribution (%) of energy intake from free sugars according to contribution (%) of NOVA food groups and ultra-processed foods subgroups, by age strata. Australian population aged 2+ years (NNPAS 2011–2012).

NOVA groups	All (N=12,153)	Age groups: Young children (2-5y) (N=822)	Older children (6-11y) (N=889)	Adolescents (12-19y) (N=1,204)	Adults (20-64y) (N=7,135)	Elderly (≥65y) (N=2,103)
Unprocessed or minimally processed foods	**0.7**	**0.3**	**0.1**	**0.2**	**0.9**	**0.7**
Processed culinary ingredients	**19.3**	**11.1**	**9.3**	**9.8**	**21.2**	**27.1**
Unprocessed or minimally processed foods + Processed culinary ingredients	**20.0**	**11.4**	**9.4**	**10.0**	**22.1**	**27.8**
Processed foods	**6.2**	**4.6**	**3.0**	**3.0**	**6.4**	**10.0**
Ultra-processed foods	**73.8**	**84.0**	**87.6**	**87.1**	**71.5**	**62.2**
Mass-produced packaged breads	0.6	0.6	0.7	0.5	0.6	0.6
Frozen and shelf stable ready meals	1.1	0.8	0.6	0.9	1.1	1.7
Fast food dishes	0.8	0.5	0.6	0.8	0.9	0.5
Pastries, buns, and cakes	6.3	7.1	8.4	5.8	6.0	6.6
Breakfast cereals	4.4	4.2	5.3	5.1	4.0	5.0
Biscuits	5.3	7.7	6.8	4.7	4.5	7.4
Fruit drinks and iced teas	17.0	26.5	22.0	22.7	15.6	12.1
Confectionary	9.0	11.0	12.3	9.5	8.7	7.4
Sausage and other reconstituted meat products	0.4	0.1	0.5	0.3	0.4	0.6
Milk-based drinks	5.1	9.6	5.5	5.0	5.0	3.6
Carbonated soft drinks	11.7	2.8	9.5	19.6	12.9	4.9
Sauces, dressing and gravies	5.6	3.4	4.3	5.0	6.1	4.8
Ice cream, ice pops and frozen yogurts	5.0	8.3	9.7	6.2	4.0	5.3
Salty snacks	0.2	0.3	0.3	0.3	0.2	0.1
Margarine and other spreads	0.5	1.2	1.1	0.5	0.4	0.5
Alcoholic distilled drinks	0.1	0.0	0.0	0.0	0.1	0.3
Other	0.6	0.1	0.0	0.1	0.8	0.9
Total	100.0	100.0	100.0	100.0	100.0	100.0

5 ASSOCIAÇÃO ENTRE O CONSUMO DE ALIMENTOS ULTRAPROCESSADOS E OCORRÊNCIA DE OBESIDADE EM ADULTOS AUSTRALIANOS

Este capítulo apresenta o artigo "*Ultra-processed food consumption and obesity in the Australian adult population (2011/12)*" de autoria de Priscila Pereira Machado, Eurídice Martinez Steele, Renata Bertazzi Levy, Maria Laura da Costa Louzada, Anna Rangan, Julie Woods, Timothy Gill, Gyorgy Scrinis, e Carlos Augusto Monteiro. O artigo será submetido para publicação na revista *International Journal of Obesity* devendo conter até 4 mil palavras.

ULTRA-PROCESSED FOOD CONSUMPTION AND OBESITY IN THE AUSTRALIAN ADULT POPULATION (2011/12)

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ABSTRACT

Background: Rapid simultaneous increases in ultra-processed foods sales and in obesity prevalence has been observed worldwide, including in Australia. Increased consumption of ultra-processed foods by the Australian population was previously shown to be systematically associated with increased risk of inadequate intakes of nutrients critical to obesity and other non-communicable diseases. This study aims to explore the association between ultra-processed food consumption and obesity among Australian adults. **Methods**: We performed a cross-sectional analysis of anthropometric and dietary data from 7,365 Australians aged ≥20 years from the National Nutrition and Physical Activity Survey 2011-12. Food consumption was evaluated through one 24-h recall. NOVA system was used to identify ultra-processed foods (industrial formulations of substances extracted or derived from foods with little if any whole food and typically added of flavours, colours and other cosmetic additives). Measured weight, height and waist circumference (WC) data were used to calculate the body mass index (BMI) and diagnosis of obesity (BMI≥30 kg/m^2), and abdominal obesity (WC≥88 cm for women and 102 cm for men). Regression models were used to evaluate the association of dietary share of ultra-processed foods (quintiles) and obesity indicators, adjusting for socio-demographic variables, physical activity and smoking. **Results:** Ultra-processed foods represent 38.9% of total energy intake among Australian adults. Significant direct dose-response associations between the dietary share of ultra-processed foods and indicators of obesity were found after adjusting for all studied confounders. In the multivariable regression analysis, those in the highest quintile of ultra-processed food consumption had significantly higher BMI (0.97 kg/m^2, 95%CI 0.42; 1.51, Ptrend<0.001) and WC (1.92 cm, 95%CI 0.57; 3.27, Ptrend<0.001), and higher odds of having obesity (OR=1.61, 95%CI 1.27; 2.04, Ptrend<0.001) and abdominal obesity (OR=1.38, 95%CI 1.10; 1.72, Ptrend=0.001) compared with those in the lowest quintile of consumption. **Conclusion:** The findings add to the growing evidence that ultra-processed food consumption is associated with or increase the risk of obesity, and support the potential role of ultra-processed foods in contributing to obesity in Australia.

Keywords: Food processing; Ultra-processed food; Obesity; Australia

5.1 INTRODUCTION

Non-communicable diseases (NCDs) are estimated to account for 89% of all deaths in Australia (AIHW, 2016; WHO, 2018), and high body mass index (BMI) remains the second greatest risk factor driving most death and disability in the country (AIHW, 2017). In the last 20 years, Australian prevalence of obesity has risen dramatically – 19% in 1995, 27% in 2012 and 31% in 2018 (Keating et al., 2015; ABS, 2019) – and currently has the fifth highest rate of obesity among the OECD countries (OECD, 2017).

The increase in global obesity rates appears to be a consequence of changes in global food systems (Swinburn et al., 2019; NCD-RisC, 2017; Global Panel, 2016; Malik, Willet, Hu, 2013; Stuckler et al., 2012), leading to the displacement of dietary patterns based on traditional meals by those that are increasingly made up of ultra-processed foods (Monteiro et al., 2013). Ultra-processed foods are defined by the NOVA food classification system as industrial formulations manufactured from substances derived from foods with little if any whole food and typically added of flavours, colours and other cosmetic additives (Monteiro et al., 2019).

The poor nutrient profile of these foods (high in salt or sugar and unhealthy fats, and low in fibre, micronutrients and phytochemicals), and the processing itself (altered physical and structural characteristics, removal of water and intense use of flavours, flavour enhancers, colors and other cosmetic additives) make them intrinsically nutritionally unbalanced, hyper-palatable and habit-forming. They dispense the necessity of culinary preparation and are omnipresent, which make them convenient and accessible. Their manufacture using low cost ingredients and the aggressive marketing of these products amplify their market advantages over unprocessed or minimally processed foods and freshly prepared meals. All those factors contribute to the replacement of traditional dietary patterns by dietary patterns based on ultra-processed foods, and also encourage the excessive consumption of energy (Monteiro et al., 2019; PAHO, 2015), conditions potentially related to the increased risk of obesity (WHO, 2018; PAHO, 2015).

A recent randomized controlled trial (RCT) showed that, compared to a diet with no ultra-processed foods, a diet based on ultra-processed foods caused an increase in energy intake of near 500 kcal per day and that, in two weeks, participants exposed to the ultra-processed diet gained 0.9 kg while participants exposed to the non-ultra-processed diet lost 0.9 kg (Hall et al., 2019). This evidence is corroborated by large observational studies conducted worldwide. Indicators of ultra-processed food consumption were shown to be associated with obesity indicators in Spain (Mendonça et al., 2016), the U.S. (Juul et al., 2018), Canada (Nardocci et al., 2018), Brazil (Canhada et al., 2019; Silva et al., 2018; Louzada et al., 2015; Canella et al., 2014), across 19 European countries (Monteiro et al., 2017), and across 80 high and middle-income countries (Vandevijvere et al., 2019).

Ultra-processed food sales are increasing globally, including in Australia (Sievert et al., 2019; Vandevijvere et al., 2019; PAHO, 2015). Previous study based on the Australian 2011-12 survey found that the increased dietary share of ultra-processed foods was systematically associated with increased risk of inadequate intakes of nutrients critical to obesity and other NCDs (Machado et al., 2019). This same survey, which simultaneously collected food intake and anthropometric data, allows testing, in a direct and unseen way, the hypothesis that the increases in the dietary share of ultra-processed foods are also associated with increases in the risk of obesity.

5.2 METHODS

Data source and collection

The data source is the National Nutrition and Physical Activity Survey (NNPAS), a household survey that collects information about Australian population's health, including anthropometric, food consumption and physical activity data. This survey studied a random sample of the Australian population, obtained by using a complex, stratified, multistage probability cluster sampling design based on the selection of strata, households and people within households. The NNPAS was conducted between May 2011 and June 2012, covering 9,519 households where 12,153 Australians were interviewed (ABS, 2013).

Food consumption

Data on food consumption were collected based on two non-consecutive 24-hour dietary recalls using an electronic survey which guides the interviewer towards preventing the interviewee from forgetting consumption items frequently omitted by those interviewed (USDA Automated Multiple-Pass Method). The first recall was applied through a face-to-face interview (n=12,153) while the second recall (n=7,735) was applied via a telephone interview conducted 8 days or more after the first interview (ABS, 2013).

Energy and nutrient intakes were estimated based on the Australian Food and Nutrient Database (AUSNUT 2011-13), which contains information for 5,740 foods and beverages consumed during the survey (FSANZ, 2014).

Mixed dishes composed of two or more food items were disaggregated using the AUSNUT 2011-2013 Food Recipe File (45% of food codes). Reported single food items and the underlying ingredients of mixed dishes were classified according to the NOVA classification system into the following four groups (and subgroups within these groups): a) unprocessed or minimally processed foods, e.g. cereals, legumes, vegetables, fruits, milk, meat; b) processed culinary ingredients, e.g. table salt, table sugar, honey, vegetable oils, butter; c) processed foods, e.g. canned vegetables in brine, salted or sugared nuts, canned fish, freshly made breads and cheeses; d) ultra-processed foods, e.g. mass-produced packaged breads, carbonated soft drinks, confectionery, cookies, breakfast ‘cereals’, flavoured yoghurts, reconstituted meat products, ready to heat meals, and packaged instant soups and noodles (Monteiro et al., 2019).

Obesity indicators

Weight, height and waist circumference measurements were obtained and registered in the surveys by research agents using digital scales, vertical stadiometers and a metal tape measure, respectively, following standard measurement techniques (ABS, 2013). BMI (weight (kg)/height (m)^2) and WC (cm) were used as indicators of adiposity. Obesity was defined as BMI $\geq$ 30 kg/m^2 (WHO, 2016), and abdominal obesity as WC $\geq$ 88 cm for women and 102 cm for men (NIH, 1998).

Covariates

Demographic covariates of interest include age, sex, educational attainment, socio-economic status (assessed with the Socio-Economic Index of Disadvantage for Areas (SEIFA), a ranking based on the relative socio-economic advantage and disadvantage of the location of the household), zones (urbanity of the household location based on the Australian Standard Geographical Classification), and country of birth. Physical activity, based on total minutes undertaken in physical activity for fitness, recreation, sport or (for) transport in last week, and smoking status were also accounted for in the analysis (ABS, 2013).

Inclusion and exclusion criteria

The analytical sample was restricted to adults aged 20-85 years. Individuals were included in the analyses if they had at least one valid dietary recall and complete data for BMI and WC. A total of 9,238 participants were in appropriate age span and eligible to be included in the analyses. Of these, we excluded pregnant and lactating women; participants who reported implausible energy intakes; and individuals with missing data for outcomes or exposure. Thus, the final sample of this study was 7,365 (Figure 1).

Data analysis

The first 24-hour recall was used for the analyses. The population was first stratified into quintiles of the dietary share of ultra-processed foods (% of total energy intake), with the lowest consumers belonging to the first quintile and the highest consumers to the fifth. Thereafter, we assessed the characteristics of participants (demographics, physical activity, smoking status, body composition and total energy intake) according to quintiles of ultra-processed food consumption. Differences in those characteristics across the dietary share of ultra-processed foods were evaluated by Pearson's χ^2 test of independence (categorical variables) and unadjusted linear regression models (treating quintile as an ordinal variable).

Multiple linear and logistic regression analyses were performed to assess the association between the dietary contribution of ultra-processed foods (quintiles) and obesity indicators, i.e. BMI (as a continuous variable and categorised to identify obesity), and WC (continuous and categorised to identify abdominal obesity). For all outcomes, we first run an unadjusted model, age-adjusted model and thereafter a multivariable model adjusted for sociodemographic variables, physical activity and smoking status.

We tested for interaction between energy share of ultra-processed foods (continuous) and age (continuous and categorised in 20-39, 40-59, ≥60 years), sex, education, income, zones, country of birth, physical activity level (total minutes continuous and categorised in inactive/active), and smoking status, by including an interaction term in the multivariable models. Subgroup analyses were performed for age group, sex and physical activity level.

Sensitivity analyses to account for potential effect of reverse causality in the relationship between ultra-processed food consumption and obesity indicators were performed excluding 2,785 individuals with extreme BMI values and following ‘special diets' at the moment of the survey or who reported a diagnosis of diabetes, heart disease or other chronic diseases which could be associated with long term dietary behaviour change (Figure 1). Multivariable models were fitted to assess the association of quintiles of the dietary share of ultra-processed foods with the obesity indicators in this subsample.

All multivariable regression models were adjusted for sex (male/female), age (continuous), years of education (completed 9 years or below including never attended, completed 10 to 12 years with no graduate degree, completed 12 years with graduate degree), income (SEIFA – quintiles), zones (major cities of Australia, inner regional, and other, which includes outer regional, remote and very remote Australia), country of birth (Australia or English country/other), level of physical activity (inactive/active, classified as active whether physical activity last week met 150 minutes recommended guidelines), and smoking status (never smoked, former smoker and current smoker).

Weighted analyses were performed using Stata survey module (version 14) to consider the effect of complex sampling procedures adopted in the NNPAS 2011-12 and in order to allow extrapolation of results for the Australian population (Stata Corp., College Station, United States).

This study was a secondary analysis using de-identified data from the ABS Basic Confidentialised Unit Record Files (CURFs), and permission to use the data was obtained. Ethics approval for the survey was granted by the Australian Government Department of Health and Ageing Departmental Ethnics Committee in 2011 (ABS, 2013).

5.3 RESULTS

Table 1 describes characteristics of the overall Australian adult population and of strata of this population that correspond to quintiles of the dietary share of ultra-processed foods. Ultra-processed foods represented 38.9% of total energy intake among Australian adults, ranging from 12.7% (range 0 to 21.7%) in the lowest quintile of ultra-processed food consumption to 74.2% (range 62.1 to 100%) in the highest quintile. Compared with participants in the lowest quintile, individuals in the highest quintile of ultra-processed food consumption were younger (Q5=40.8 *v.* Q1=48.4 years, $P<0.001$), more likely to belong to the poorest income quintile (22.8 *v.* 15.5%, $P<0.001$), be Australian or from English country (88.0 *v.* 70.3%, $P<0.001$), inactive (53.5 *v.* 41.8%, $P<0.001$), current smoker (26.4 *v.* 17.0%, $P<0.001$), and have higher BMI (27.7 *v.* 26.7 kg/m^2, $P<0.001$), WC (92.9 *v.* 91.1 cm, $P<0.001$), prevalence of obesity (30.9 *v.* 20.7%, $P<0.001$), prevalence of abdominal obesity (40.5 *v.* 35.1%, $P<0.001$), and total energy intake (2,138.5 *v.* 1,924.5 kcal, $P<0.001$), and less likely to be higher educated (17.7 *v.* 29.9%, $P<0.001$) and to live in major cities (68.6 *v.* 75.2%, $P=0.002$) (Table 1).

Crude, age-adjusted and multivariable models showed that the dietary share of ultra-processed foods was significantly associated with higher BMI and WC, and greater odds of having obesity and abdominal obesity among Australian adults (Ptrend≤0.001 for all outcomes) (Tables 2 and 3). Significant direct dose-response associations between the dietary share of ultra-processed foods and BMI and obesity were found after adjusting for sociodemographic variables, physical activity and smoking (Tables 2 and 3). In the multivariable regression analyses, we observed that those in the highest quintile of ultra-processed food consumption had mean BMI 0.97 kg/m^2 (95% CI 0.42; 1.51) and WC 1.92 cm (95% CI 0.57; 3.27) higher compared with those in the lowest quintile of consumption (Table 2). The adjusted odds ratios (OR) of having obesity and abdominal obesity were, respectively, 1.61 (95% CI 1.27; 2.04) and 1.38 (95% CI 1.10; 1.72) in the top quintile of ultra-processed food consumption (Table 3).

Analyses of interactions are presented in Table S1. Subgroup analyses showed that the trend toward positive associations for all obesity indicators remained in all age groups, sex and physical activity level (Figure 2). The only exception was the statistically non-significant association with WC and abdominal obesity among adults aged 20-39 years (Tables S2 and S3). The effect of ultra-processed food consumption on BMI and WC was stronger among people aged ≥40 years, female, and inactive, and on obesity and abdominal obesity was stronger among people aged ≥40 years, male, and inactive. However, these differences were not statistically significant (Figure 2, Tables S2 and S3).

Sensitivity analyses considering potential effect of reverse causality show an increase in the magnitude of the associations in the fifth quintile of ultra-processed food consumption for all obesity indicators in comparison to the multivariable models performed in the full analytical sample (Table 4).

5.4 DISCUSSION

In this nationally representative cross-sectional study, we investigated the association of ultra-processed food consumption with obesity among Australian adults. We found that higher consumption of ultra-processed foods was significantly associated with greater body mass index and waist circumference, and greater odds of having obesity and abdominal obesity. Trends towards positive associations of ultra-processed food consumption and obesity indicators were observed in both men and women and across age groups and levels of physical activity.

Australians whose diets were based on ultra-processed foods (>62% of total energy intake) had 0.97 units higher body mass index, 1.92 cm greater waist circumference, and were 61% and 38% more likely of having obesity and abdominal obesity, respectively, than individuals whose diets were not based on ultra-processed foods (<22% of energy intake). The findings of the present study are supported by existing literature showing causal relationship between ultra-processed food consumption and weight gain (Hall et al., 2019). In the RCT conducted by Hall and cols. (2019), participants gained, on average, 0.9 ± 0.3 kg during the ultra-processed diet and lost, on average, 0.9 ± 0.3 kg during the diet based on non-ultra-processed foods.

In accordance with these findings, consumption of ultra-processed foods was found to be associated with 9-year incidence of overweight or obesity in a prospective cohort of Spanish middle-aged adult university graduates (Mendonça et al., 2016), weight gain in a cohort of American pregnant women (Rohatgi et al., 2017), incidence of obesity or of higher weight gain among Brazilian adults (Canhada et al., 2019), and in cross-sectional studies involving nationally representative sample of adults in the U.S. (Juul et al., 2018), Canada (Nardocci et al., 2018) and Brazil (Louzada et al., 2015). An ecological study including 19 European countries found a significant positive association between national household availability of ultra-processed foods and national prevalence of obesity among adults (Monteiro et al., 2017). Similarly, study across 80 high and middle-income countries found a positive association of annual changes in sales per capita of ultra-processed products with adult BMI trajectories (Vandevijvere et al., 2019).

The mechanisms underlying the association between ultra-processed food consumption and obesity are not fully established. However, this likely results from a combination of the obesogenic nutritional profile of these foods (Spiteri et al., 2018; Ni Mhurchu et al., 2016), non-nutritional mechanisms related to the processing itself (Miclotte & de Wiele, 2019; Hall et al., 2019; Fardet, 2016; Ludwig, 2011), and the displacement of nutritious unprocessed and minimally processed foods and fresh meals prepared with these foods (Monteiro et al., 2018).

Population-based studies conducted in several countries have shown that the energy share of ultra-processed foods impacted negatively on the intake of nutrients linked to obesity, such as free or added sugars, total fats, dietary energy density, and fibre (Machado et al., 2019; Koiwai et al., 2019; Parra et al., 2019; Chen et al, 2018; Rauber et al., 2018; Louzada et al., 2018; Cediel et al., 2018; Fardet, 2017; Steele et al., 2017; Moubarac et al., 2017; Steele et al., 2016). In Australia, the risk of having diets that do not comply with dietary goals recommended for the prevention of obesity increased linearly across quintiles of dietary share of ultra-processed foods, attaining the astonishing 3.9 higher risk of excessive free sugars intake among the highest consumers of ultra-processed foods (Machado et al., 2019).

Also, processing techniques applied in the manufacture of ultra-processed foods, such as the partial or total withdrawal of water, the deconstruction of the original food matrix structure, and the use of high amounts of sugar, salt, fats, and cosmetic additives, that enhance oro-sensory properties and energy density of these foods, may increase eating rate (grams consumed per minute) and override endogenous satiety and appetite signalling, thereby resulting in greater overall intake (Hall et al., 2019; Fardet, 2016; Ogden et al., 2013; Ludwig, 2011; de Graaf and Kok, 2010; Rolls, 2009). Ultra-processed beverages may have even stronger effect by adding to total energy intake without displacing energy from solid foods, as well as affecting subsequent meals due to incomplete compensatory reduction in energy intake (Gombi-Vaca et al., 2016; Malik et al., 2013; DellaValle et al., 2005).

The role of food processing on gut system has recently been emphasised facing evolving evidence showing the effect of the gut microbiota on energy homeostasis and lipid accumulation of the host, and consequent weight gain and obesity (Miclotte & de Wiele, 2019; Zinocker & Lindseth, 2018; Boulange et al., 2016; Hamilton & Raybould, 2016). Diets based on ultra-processed foods may disrupt gut-brain axis satiety signalling, induce microbiota dysbiosis, gut inflammation, and compromise gut barrier function and the supply of nutrients to the gut epithelium due to the presence of non-caloric artificial sweeteners, emulsifiers, advanced glycation end products, and the low content of micronutrients and phytosterols in these foods (Miclotte & de Wiele, 2019; Small and DiFeliceantonio, 2019; Zinocker & Lindseth, 2018).

Ultra-processed foods are frequently designed to be convenient and able to be consumed anywhere, as snacks rather than as regular meals (Monteiro et al., 2019; Monteiro et al., 2018; Monteiro et al., 2013). They are accessible (Cameron et al., 2015), affordable (Moubarac et al., 2013b), aggressively marketed (Kelly et al., 2019; Zorba et al., 2019; Pulker et al., 2018; Cameron et al., 2015; Ni Mhurchu et al., 2016), and their portion sizes are increasing over time (Zheng et al., 2016). These characteristics may also induce the displacement of freshly prepared meals and stimulate overconsumption of energy (Monteiro et al., 2019; PAHO, 2015).

The consumption of ultra-processed foods is increasing worldwide, already comprising the majority of calories consumed in high-income countries such as the U.K. (Rauber et al., 2018), the U.S. (Steele et al., 2017), and Canada (Moubarac et al., 2017). Besides weight gain and obesity, the consumption of ultra-processed foods has been associated with increased risk of all-cause mortality (Rico-Campà et al., 2019; Kim et al., 2019; Schnabel et al., 2019), hypertension and cardiovascular diseases (Srour et al., 2019; Mendonça et al., 2017), metabolic syndrome (Martínez Steele et al., 2019; Lavigne et al., 2018), cancer (Fiolet et al., 2018), and gastrointestinal disorders (Schnabel et al., 2018).

Given the adverse outcomes related to ultra-processed food consumption, dietary advice and policy actions could be aimed to decrease consumption of these foods, whilst promoting the availability, accessibility, and affordability of unprocessed and minimally processed foods (PAHO, 2019; Lawrence & Baker, 2019; Monteiro et al., 2018). Furthermore, the role of food processing, in particular of ultra-processed foods in contributing to obesity in Australia, should be considered in the current discussion for an overarching strategy to tackle obesity in the country (Australian Department of Health, 2019).

Our study has several strengths. To the best of our knowledge, this is the first study to analyse the association of ultra-processed food consumption with obesity in Australia. We used the most up-to-date, individual-level dietary survey data taken from a nationally representative sample of Australian adults, increasing generalisability. The analyses were based on the NOVA food classification system (Monteiro et al., 2019), which has been recognised by UN agencies as a relevant approach for linking dietary intake, obesity and NCDs (PAHO, 2019; FAO, 2016; FAO, 2015; PAHO, 2015). NOVA system was applied into disaggregated food codes in the Australian food composition database, which enabled determining food processing level based on standardised, objective and clear criteria, reducing the chance of misclassification. Availability of collected sociodemographic, physical activity and smoking data allowed adjustment for several confounders, to test interactions and consistency among population groups, and provided novel evidence on group-specific associations. Although BMI is considered a useful tool to asses body mass at the population level, the inclusion of a second indicator of adiposity (waist circumference) strengthens our findings and adds valuable information on body fat distribution (Stevens et al., 2010).

Nevertheless, there are also limitations to the interpretation of our findings. First, this is a cross-sectional study, and thus temporality and causality cannot be established. However, our results are biologically plausible and consistent with the randomized controlled trial that has assessed the short-term impact of ultra-processed diets on energy intake and weight gain (Hall et al., 2019), and with a few longitudinal studies that have assessed the association between the dietary share of ultra-processed foods and the incidence of obesity or of higher weight gain (Canhada et al., 2019; Rohatgi et al., 2017; Mendonça et al., 2016). Besides, reverse causality cannot be ruled out. In fact, the magnitude of the associations increased in the sensitivity analyses excluding individuals on ‘special diets’, with extreme BMI values or with diagnosis of diet-related chronic diseases that may have changed dietary behaviour (Table 4). Although we controlled for vast array of potential confounders, residual confounding due to unmeasured confounders (e.g. parity, menopause) could explain at least in part the associations.

In addition, limitations related to the dietary assessment instrument deserve mention. The analyses were based on a single recall and may not represent the usual diet. Although obesity could have changed individuals’ health behaviours, including diet, these changes are also likely to have occurred in the consumption of ultra-processed foods, by reducing overall intake among obese people, hence attenuating the magnitude of the associations. Misreporting is an inherent potential bias of the 24-h recall. Studies suggest that foods usually considered unhealthy (e.g. ultra-processed foods like confectionary, cakes, chips) are more likely to be under-reported (Lafay et al., 2000). Should differential information bias exist, the associations would hence be biased towards the null. Finally, dietary survey and food composition database were not designed specifically to categorise foods according to characteristics of industrial processing, and so misclassification of foods at the individual level cannot be excluded. However, standardised, objective and clear criteria were considered, plus several independent researchers reviewed the classification, and a conservative approach (assigning lower level of processing) was considered in case of uncertainty.

5.5 CONCLUSION

In conclusion, our findings add to the growing evidence that ultra-processed food consumption is associated with or increase the risk of obesity, and support the potential role of ultra-processed foods in contributing to obesity in Australia. Despite the cross-sectional nature of the study, our results are biologically plausible and underpinned by evidence derived from experimental and observational studies from several high and middle-income countries showing similar results. Importantly, our study contributes to the evolving evidence on the role of food processing in adiposity and is the first one to present an association between ultra-processed food consumption and obesity in a nationally representative sample of Australian adults.

Future studies should be enlarged to populations around the world, to present context-dependent magnitudes and drivers of ultra-processed food consumption and obesity, and mechanistic studies are needed to clarify underlying plausible causal pathways that explain links between food processing and adiposity. This evidence is relevant to inform policy makers and for dietary advice at the population and clinical levels.

5.6 REFERENCES

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5.7 TABLES

Table 1. Characteristics of the population according to dietary share of ultra-processed foods. Australian population aged ≥20 years (NNPAS 2011–2012), *n* 7,365.

	Dietary share of ultra-processed foods (quintiles)[a]						
	All	Q1	Q2	Q3	Q4	Q5	P-value*
Age (years), mean	46.7	48.4	48.6	47.5	46.4	40.8	<0.001
Sex (%)							0.493
Male	51.7	50.4	50.7	51.7	53.5	52.9	
Female	48.3	49.6	49.3	48.3	46.5	47.1	
Years of education (%)							<0.001
≤9 years	13.5	13.7	13.3	13.8	14.4	12.1	
10 to 12 years	61.8	56.4	59.3	62.4	64.1	70.2	
10 to 12 years with graduate degree	24.7	29.9	27.4	23.8	21.5	17.7	
Income (SEIFA) (%)							<0.001
Quintile 1- greater disadvantage	17.7	15.5	16.2	16.6	19.6	22.8	
Quintile 2	19.9	18.7	20.4	19.9	19.9	20.7	
Quintile 3	21.1	19.7	18.9	23.4	23.0	21.4	
Quintile 4	19.1	19.8	21.6	18.8	17.3	16.3	
Quintile 5- greater advantage	22.2	26.3	22.8	21.4	20.2	18.8	
Zones (%)							0.002
Major cities	71.5	75.2	72.9	72.9	66.4	68.6	
Inner regional	19.3	16.5	18.6	18.0	22.5	22.5	
Other	9.2	8.3	8.5	9.1	11.1	8.9	
Country of birth (%)							<0.001
Australia or English Country	79.8	70.3	77.1	81.7	86.4	88.0	
Other	20.2	30.0	22.8	18.2	13.5	12.0	
Physical activity[b] (%)							<0.001
Inactive	48.0	41.8	47.1	47.5	53.1	53.5	
Active	52.0	58.2	52.9	52.5	46.9	46.5	
Smoking status (%)							<0.001
Never smoked	49.8	50.4	52.1	51.3	48.2	45.7	
Former smoker	31.8	32.6	33.4	31.8	32.2	27.9	
Current smoker	18.4	17.0	14.5	16.9	19.6	26.4	
BMI (kg/m^2)	27.4	26.7	27.3	27.6	27.9	27.7	<0.001
Obesity (BMI ≥30kg/m^2) (%)	26.5	20.7	26.3	27.2	29.9	30.9	<0.001
Waist circumference (cm)	92.8	91.1	92.9	93.2	94.8	92.9	<0.001
Abdominal obesity[c] (%)	40.2	35.1	41.0	39.7	46.2	40.5	<0.001
Total energy intake (kcal)	2011.7	1924.5	2004.0	2001.0	2036.1	2138.5	<0.001

[a]Percentage of energy intake from ultra-processed foods. Mean (range): All = 38.9 (0 to 100); Q1= 12.7 (0 to 21.7); Q2= 28.4 (21.7 to 34.6); Q3= 40.3 (34.6 to 46.6); Q4= 54.0 (46.6 to 62.1); Q5= 74.2 (62.1 to 100)
[b]Active whether physical activity last week met 150 minutes recommended guidelines
[c]Defined as waist circumference ≥ 88 cm for women and 102 cm for men.
*P-value for continuous variables is estimated through unadjusted linear regression, treating quintile as an ordinal variable, and Pearson's $\chi 2$ for categorical variables

Table 2. Association of dietary share of ultra-processed foods (% of total energy) with BMI and waist circumference among Australians aged ≥20 years (NNPAS 2011–2012), *n* 7,365.

	Dietary share of ultra-processed foods (quintiles)[a]										
	Q1		Q2		Q3		Q4		Q5		
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	P-trend
BMI (kg/m^2)											
Unadjusted	0.0	Ref.	0.66*	(0.21; 1.12)	0.86*	(0.38; 1.32)	1.26*	(0.77; 1.75)	1.06*	(0.50; 1.61)	<0.001
Age-adjusted	0.0	Ref.	0.66*	(0.21; 1.10)	0.91*	(0.45; 1.37)	1.38*	(0.90; 1.86)	1.51*	(0.97; 2.06)	<0.001
Multivariable[b]	0.0	Ref.	0.52*	(0.07; 0.95)	0.66*	(0.20; 1.11)	0.96*	(0.47; 1.45)	0.97*	(0.42; 1.51)	<0.001
Waist circumference (cm)											
Unadjusted	0.0	Ref.	1.73*	(0.48; 2.97)	2.00*	(0.71; 3.29)	3.63*	(2.31; 4.94)	1.77*	(0.29; 3.26)	<0.001
Age-adjusted	0.0	Ref.	1.71*	(0.52; 2.89)	2.23*	(0.99; 3.47)	4.12*	(2.85; 5.39)	3.60*	(2.18; 5.02)	<0.001
Multivariable[b]	0.0	Ref.	1.26*	(0.19; 2.33)	1.42*	(0.30; 2.54)	2.66*	(1.46; 3.87)	1.92*	(0.57; 3.27)	<0.001

BMI: body mass index; β: regression coefficient; CI: confidence interval

Ref.: Reference group

[a]See previous table

[b]Adjusted for sex, age, educational attainment, income, zones, country of birth, level of physical activity and smoking status

*$p<0.05$

Table 3. Association of dietary share of ultra-processed foods (% of total energy) with obesity and abdominal obesity among Australians aged ≥20 years (NNPAS 2011–2012), *n* 7,365.

	Dietary share of ultra-processed foods (quintiles)[a]										
	Q1		Q2		Q3		Q4		Q5		
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	P-trend
Obesity (BMI≥30kg/m^2)											
Unadjusted	1.0	Ref.	1.36*	(1.11; 1.67)	1.43*	(1.16; 1.76)	1.62*	(1.30; 2.00)	1.71*	(1.36; 2.14)	<0.001
Age-adjusted	1.0	Ref.	1.37*	(1.11; 1.68)	1.46*	(1.18; 1.80)	1.68*	(1.36; 2.09)	1.97*	(1.56; 2.47)	<0.001
Multivariable[b]	1.0	Ref.	1.29*	(1.05; 1.59)	1.33*	(1.07; 1.64)	1.44*	(1.15; 1.80)	1.61*	(1.27; 2.04)	<0.001
Abdominal obesity[c]											
Unadjusted	1.0	Ref.	1.29*	(1.07; 1.55)	1.22*	(1.01; 1.47)	1.59*	(1.31; 1.92)	1.26*	(1.03; 1.55)	0.001
Age-adjusted	1.0	Ref.	1.31*	(1.08; 1.58)	1.28*	(1.05; 1.55)	1.77*	(1.45; 2.17)	1.69*	(1.36; 2.10)	<0.001
Multivariable[b]	1.0	Ref.	1.24*	(1.02; 1.51)	1.16	(0.95; 1.42)	1.53*	(1.24; 1.88)	1.38*	(1.10; 1.72)	0.001

BMI: body mass index; OR: odds ratio; CI: confidence interval
Ref.: Reference group
[a]See previous table
[b]Adjusted for sex, age, educational attainment, income, zones, country of birth, level of physical activity and smoking status
[c]Defined as waist circumference ≥ 88 cm for women and 102 cm for men.
*$p<0.05$

Table 4. Sensitivity analyses of the association of dietary share of ultra-processed foods (% of total energy) with indicators of adiposity considering potential effect of reverse causality†. Australians aged ≥20 years (NNPAS 2011–2012), *n* 4,580.

	Dietary share of ultra-processed foods (quintiles)[a]										
	Q1		Q2		Q3		Q4		Q5		
	β/OR	95% CI	β/OR	95% CI	β/OR	95% CI	β/OR	95% CI	β/OR	95% CI	P-trend
BMI (kg/m^2), β	0.0	Ref.	0.30	(-0.17; 0.78)	0.51*	(0.07; 1.01)	0.97*	(0.44; 1.51)	1.11*	(0.51; 1.71)	<0.001
WC (cm), β	0.0	Ref.	0.40	(-0.24; 2.41)	1.08	(-0.25; 2.41)	1.89*	(0.57; 3.22)	2.42*	(0.87; 3.96)	<0.001
Obesity (BMI≥30kg/m^2), OR	1.0	Ref.	0.99	(0.72; 1.37)	1.27	(0.93; 1.74)	1.34	(0.98; 1.83)	1.68*	(1.21; 2.33)	<0.001
Abdominal obesity[b], OR	1.0	Ref.	1.24	(0.95; 1.63)	1.11	(0.84; 1.45)	1.46*	(1.12; 1.90)	1.68*	(1.27; 2.23)	<0.001

BMI: body mass index; WC: waist circumference; β: regression coefficient; OR: odds ratio; CI: confidence interval
Ref.: Reference group
†Excluding people following special diets or who reported diagnosis of diabetes, heart disease or other diet-related chronic diseases. Analyses adjusted for sex, age, educational attainment, income, zones, country of birth, level of physical activity and smoking status
[a]Percentage of energy intake from ultra-processed foods. Mean (range): All = 39.9 (0 to 100); Q1= 11.6 (0 to 19.9); Q2= 26.3 (19.9 to 32.2); Q3= 37.8 (32.2 to 43.5); Q4= 50.9 (43.5 to 59.8); Q5= 73.2 (59.8 to 100).
[b]Defined as waist circumference ≥ 88 cm for women and 102 cm for men.
*$p<0.05$

5.8 FIGURES

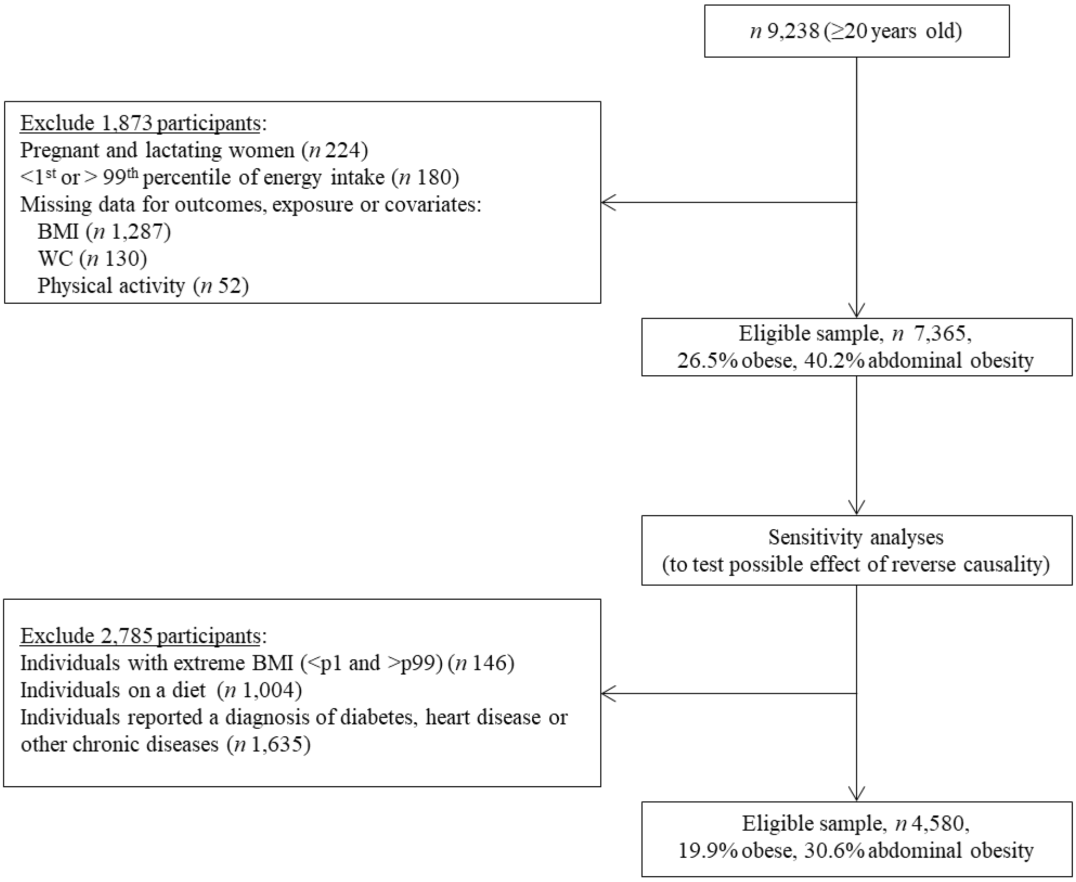

Fig. 1 Flowchart showing participants excluded in each analysis (NNPAS 2011-12).

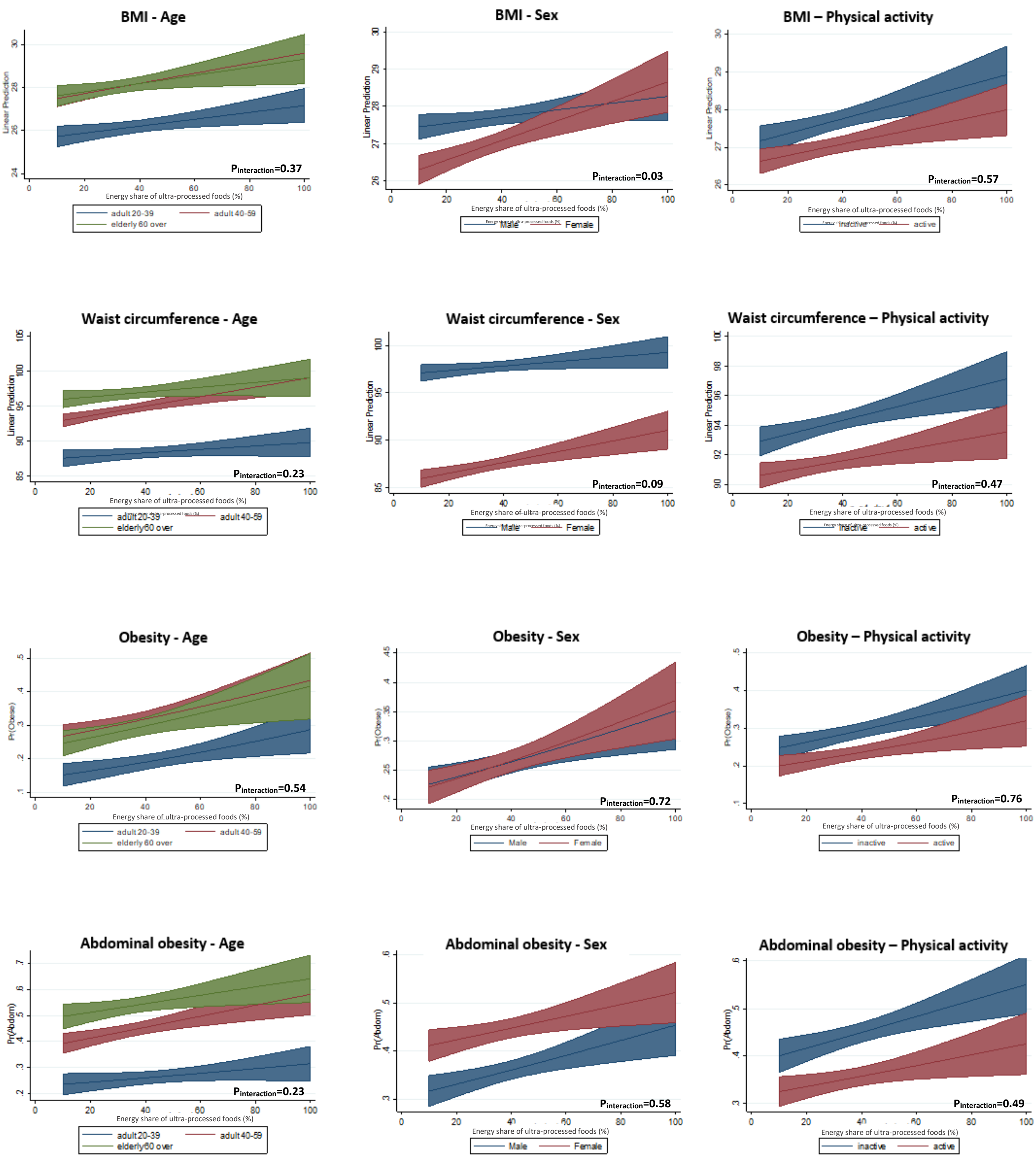

Fig 2. Subgroup analysis: joint association of dietary share of ultra-processed foods (% of total energy) with indicators of adiposity, by age, sex and level of physical activity. Australians aged ≥20 years (NNPAS 2011–2012), n 7,365. Abbreviation: BMI, body mass index. Adjusted for age (except in age-stratified analyses), sex (except in sex-stratified analyses), educational attainment, income, zones, country of birth, level of physical activity (except in physical activity-stratified analyses) and smoking status.

5.9 SUPPLEMENTARY MATERIAL

Table S1. Interactions in the relationship between dietary share of ultra-processed foods and obesity indicators, by sociodemographic characteristics, physical activity and smoking status. Australian population aged ≥20 years (NNPAS 2011–2012), *n* 7,365.

	P-value for interaction*			
	BMI (kg/m^2)	Obesity (BMI≥30 kg/m^2)	WC (cm)	Abdominal obesity[a]
Age (years)	0.232	0.347	0.149	0.177
Age group	0.367	0.541	0.229	0.226
Sex	0.027	0.716	0.094	0.583
Education	0.571	0.216	0.688	0.850
Income	0.682	0.217	0.786	0.934
Zones	0.816	0.872	0.813	0.522
Country of birth	0.941	0.584	0.802	0.745
Physical activity (minutes/week)	0.398	0.618	0.670	0.780
Physical activity level	0.572	0.755	0.466	0.486
Smoking	0.301	0.082	0.124	0.004

BMI: body mass index; WC: waist circumference

*$p<0.05$ indicates significant interaction.

[a]Defined as waist circumference ≥ 88 cm for women and 102 cm for men.

Table S2. Subgroup analysis: Association between dietary share of ultra-processed foods and BMI and WC by age, sex, and physical activity. Australian population aged ≥20 years (NNPAS 2011–2012), *n* 7,365.

	Dietary share of ultra-processed foods[a]		
	β[†]	**95% CI**	**$P_{interaction}$**
BMI (kg/m²)			
Age			0.367
20-39	0.15	(0.02 to 0.28)	
40-59	0.20	(0.08 to 0.32)	
≥60 years	0.22	(0.05 to 0.39)	
Sex			0.027
Male	0.11	(0.02 to 0.21)	
Female	0.23	(0.10 to 0.35)	
Physical activity			0.572
Inactive	0.21	(0.08 to 0.32)	
Active	0.14	(0.03 to 0.24)	
WC (cm)			
Age			0.229
20-39	0.27	(-0.06 to 0.60)	
40-59	0.59	(0.29 to 0.89)	
≥60 years	0.37	(0.02 to 0.77)	
Sex			0.094
Male	0.31	(0.05 to 0.57)	
Female	0.47	(0.17 to 0.77)	
Physical activity			0.466
Inactive	0.49	(0.20 to 0.78)	
Active	0.29	(0.02 to 0.56)	

BMI: body mass index; WC: waist circumference; β: regression coefficient; CI: confidence interval
[a]For an increase of 10% of the proportion of ultra-processed food intake in the diet
[†]Adjusted for age (except in age-stratified analyses), sex (except in sex-stratified analyses), educational attainment, income, zones, country of birth, level of physical activity (except in physical activity-stratified analyses) and smoking status.

Table S3. Subgroup analysis: Association between dietary share of ultra-processed foods and obesity and abdominal obesity by age, sex, and physical activity. Australian population aged ≥20 years (NNPAS 2011–2012), *n* 7,365.

	Dietary share of ultra-processed foods[a]		
	Odds ratio[†]	**95% CI**	**$P_{interaction}$**
Obesity (BMI≥30kg/m2)			
Age			0.541
20-39	1.09	(1.02 to 1.16)	
40-59	1.08	(1.02 to 1.14)	
≥60 years	1.11	(1.04 to 1.18)	
Sex			0.716
Male	1.09	(1.03 to 1.14)	
Female	1.07	(1.02 to 1.12)	
Physical activity			0.755
Inactive	1.09	(1.04 to 1.14)	
Active	1.07	(1.02 to 1.13)	
Abdominal obesity[b]			
Age			
20-39	1.05	(0.99 to 1.11)	0.226
40-59	1.08	(1.03 to 1.14)	
≥60 years	1.08	(1.01 to 1.14)	
Sex			0.583
Male	1.08	(1.03 to 1.13)	
Female	1.05	(1.01 to 1.09)	
Physical activity			0.486
Inactive	1.08	(1.03 to 1.13)	
Active	1.05	(1.01 to 1.10)	

CI: confidence interval
[a]For an increase of 10% of the proportion of ultra-processed food intake in the diet
[†]Adjusted for age (except in age-stratified analyses), sex (except in sex-stratified analyses), educational attainment, income, zones, country of birth, level of physical activity (except in physical activity-stratified analyses) and smoking status.
[b]Defined as waist circumference ≥ 88 cm for women and 102 cm for men.

6 CONSIDERAÇÕES FINAIS

O presente estudo trouxe resultados robustos e inéditos sobre padrões de consumo de alimentos ultraprocessados e sua influência sobre a qualidade nutricional da dieta e ocorrência de obesidade na população australiana, utilizando dados da pesquisa de representatividade nacional mais atual com dados de consumo efetivo no país, bem como utilizando a classificação de alimentos NOVA, reconhecida por sua capacidade de explicar as relações contemporâneas entre alimento, nutrição e as condições de saúde das populações (Monteiro et al., 2019a; Monteiro et al., 2019b; Monteiro et al., 2018; FAO, 2016a; FAO, 2015; PAHO, 2015).

Nossa hipótese inicial, que a participação de alimentos ultraprocessados efetivamente prediz a qualidade nutricional da dieta e se associa à ocorrência de obesidade na Austrália, foi confirmada. Alimentos ultraprocessados contribuem com mais de 40% do consumo energético diário no país, notavelmente a partir de pães, refeições prontas, *fast foods*, e produtos de panificação. A participação de alimentos ultraprocessados na dieta australiana impactou negativamente no consumo dos demais grupos de alimentos e na ingestão diária de nutrientes preditores de obesidade e doenças crônicas não-transmissíveis, a saber açúcar livre, gorduras total, saturada e *trans*, sódio, potássio, fibra e densidade energética, mostrando-se um indicador chave para avaliação de padrões alimentares. Os resultados deste estudo confirmam o perfil nutricional desfavorável dos alimentos ultraprocessados e de dietas baseadas nesses alimentos, e reforçam a importância de se reduzir seu consumo para se atingir as recomendações nutricionais para a prevenção de obesidade e doenças crônicas no país.

O impacto do consumo de alimentos ultraprocessados na ingestão de açúcar livre em diferentes grupos etários na Austrália foi avaliado de forma aprofundada nesta tese, face às evidências robustas sobre o efeito deletério de açúcares livres para a saúde, e a janela de oportunidade do uso desta evidência para subsidiar o caloroso debate atual sobre as políticas de açúcar na Austrália (Australian Department of Health, 2019; Obesity Policy Coalition, 2018). O consumo de alimentos ultraprocessados foi diretamente associado ao maior conteúdo de açúcar livre na dieta e ao consumo excessivo deste nutriente em todas as faixas etárias. A qualidade da alimentação de crianças e adolescentes merece especial atenção, dado que poucos estudos anteriores a este exploraram o consumo de alimentos ultraprocessados nestas faixas etárias. Faz-se notar que crianças maiores de cinco anos e adolescentes, consumindo mais da metade das suas calorias a partir de alimentos ultraprocessados, foram os grupos etários de maior consumo desses alimentos e com as maiores prevalências de consumo excessivo de açúcar livre. Ressalta-se, a partir dos resultados deste estudo, que os esforços para redução do consumo de açúcares livres na Austrália devem ser focados na redução do consumo de alimentos ultraprocessados.

As evidências apresentadas nestes dois estudos mostram que a substituição de alimentos in natura e minimamente processados e suas preparações culinárias por alimentos ultraprocessados está associada a uma deterioração geral da dieta dos australianos. Estes achados possuem implicações para a saúde pública incluindo o claro potencial de aumento no risco de obesidade e diversas outras doenças crônicas não transmissíveis.

A associação entre o consumo de alimentos ultraprocessados e ocorrência de obesidade foi testada em uma amostra representativa de adultos australianos. Observou-se que o consumo de alimentos ultraprocessados foi diretamente associado ao maior IMC, circunferência da cintura (CC), e risco de obesidade (IMC$\geq$30kg/m^2) e obesidade abdominal (CC$\geq$88/102cm para mulheres e homens, respectivamente) em adultos australianos. Relações dose-resposta foram observadas nas associações entre o consumo de alimentos ultraprocessados e indicadores de obesidade, e tendências positivas foram observadas em todos os grupos etários, em ambos os sexos e níveis de atividade física. Apesar do desenho transversal deste estudo, estes achados são biologicamente plausíveis e corroborados por estudo experimental e estudos observacionais de base populacional, e demonstram, portanto, a potencial contribuição dos alimentos ultraprocessados na epidemia de obesidade na Austrália.

Por fim, destaca-se que esta tese apresenta um conjunto de evidências inéditas para melhorar a qualidade da alimentação na Austrália com vistas à prevenção de obesidade e doenças crônicas no país, e propicia reflexões importantes sobre as implicações destes achados para as pesquisas e políticas públicas na área de alimentação, nutrição e saúde.

6.1 IMPLICAÇÕES PARA PESQUISAS EM ALIMENTAÇÃO, NUTRIÇÃO E SAÚDE

Os paradigmas da ciência da nutrição traçam o entendimento sobre a natureza, a extensão, causas e possíveis soluções para os problemas em nutrição em saúde pública, moldando não apenas a produção científica per si, mas também as ações políticas derivadas dessas descobertas e recomendações (Ridgway et al., 2019). Esta tese baseou-se em uma visão ampliada de alimentação e, portanto, apresenta alternativas de condução e interpretação dos achados para se superar uma visão reducionista da ciência da nutrição.

Os achados deste estudo corroboram a literatura existente e crescente sobre o papel do processamento de alimentos como preditor da qualidade nutricional das dietas e saúde das populações (Monteiro et al., 2019b; Monteiro et al., 2018). Recente documento publicado pela FAO (2019), organizado por pesquisadores do Nupens/USP, incluindo a autora desta tese, apresenta uma compilação dos estudos sobre o impacto do consumo de alimentos ultraprocessados sobre a qualidade nutricional das dietas e na ocorrência de doenças crônicas não transmissíveis. Resultados de 45 estudos publicados em revistas científicas revisadas por pares mostram associações significativas e relações dose-resposta entre o consumo de alimentos ultraprocessados e perfis nutricionais de dietas promotores de doenças crônicas não transmissíveis. Do mesmo modo, associações plausíveis, significantes e relações dose-resposta foram observadas em estudos com desfechos de obesidade, doenças cardiovasculares e alterações metabólicas, câncer, depressão, transtornos gastrointestinais e mortalidade (Monteiro et al., 2019b).

Ademais, particularmente relevante, esta tese compõe um projeto multipaíses e, portanto, contribui parar alargar a variabilidade na exposição ao consumo de alimentos ultraprocessados, ampliando o potencial de generalização de resultados, assim como contribui para a internacionalização de uma linha de pesquisa iniciada no Brasil.

Apesar de crescente, estudos aplicando a classificação NOVA ainda são escassos, especialmente aqueles experimentais e longitudinais. Destaca-se que a NOVA foi considerada a classificação de alimentos baseada no processamento mais específica, coerente e compreensiva (Moubarac et al., 2014). O guia da FAO sobre como incorporar informações sobre características do processamento de alimentos na coleta de dados de consumo alimentar

(FAO, 2015), além da publicação que detalha, de forma simplificada, como identificar alimentos ultraprocessados (Monteiro et al., 2019a), podem apoiar pesquisadores na condução de seus estudos.

Outrossim, futuros estudos devem ser ampliados a contextos com sistemas alimentares contrastantes (Monteiro et al., 2018), de modo a se identificar diferentes padrões e tendências temporais do consumo de alimentos ultraprocessados, as características sociodemográficas destes consumidores, os determinantes sociais e comerciais deste consumo, incluindo aqueles referentes à informação, oferta, custo, habilidades culinárias, tempo e publicidade de alimentos ultraprocessados, o impacto em diferentes desfechos de saúde, e possíveis soluções contexto-específicas. Igualmente importante são os estudos que buscam esclarecer os mecanismos biológicos subjacentes à relação entre o consumo de alimentos ultraprocessados e desfechos de saúde, e estudos interdisciplinares sobre os impactos sociais, culturais, econômicos e ambientais dos alimentos ultraprocessados.

6.2 IMPLICAÇÕES PARA POLÍTICAS PÚBLICAS EM ALIMENTAÇÃO, NUTRIÇÃO E SAÚDE

As evidências apresentadas neste estudo clamam por ações integradas e articuladas entre diversos setores e atores do sistema alimentar, para a garantia de ambientes que propiciem a mudança de conduta dos indivíduos e da sociedade. A mensagem que se deixa aos formuladores de políticas públicas a partir deste estudo é encorajadora: australianos cujas dietas são baseadas em alimentos in natura ou minimamente processados possuem maior chance de atingirem os níveis de ingestão de nutrientes internacionalmente recomendados para a prevenção de doenças crônicas, e possuem, de modo geral, menor risco de desenvolver obesidade.

Considerando o elevado consumo de alimentos ultraprocessados pela população australiana, seu impacto negativo sobre a qualidade da dieta e obesidade demonstrados neste estudo (resultados corroborados por estudos em outros países), os demais efeitos deletérios à saúde já conhecidos do consumo desses alimentos, e os potenciais impactos sobre o meio ambiente, a economia, cultura e as relações sociais, recomendações nutricionais e ações políticas devem ser voltadas à redução da oferta e consumo de alimentos ultraprocessados (Monteiro et al., 2019b; Lawrence & Baker, 2019; Monteiro et al., 2018).

O que as pessoas comem é grandemente afetado pela disponibilidade dos alimentos, pelo preço a que são vendidos, e pelas normas culturais e sociais. O ambiente alimentar é o espaço onde os consumidores se envolvem com o sistema alimentar para tomar suas decisões sobre a aquisição, preparo e consumo dos alimentos. O ambiente, portanto, molda as escolhas alimentares dos indivíduos, e por isso são tão importantes as ações que transformem o ambiente alimentar de modo a favorecer escolhas alimentares mais saudáveis (FAO/WHO, 2018).

Diversas experiências exitosas e recomendações internacionais podem inspirar a Austrália no caminho para a redução do consumo de alimentos ultraprocessados. Destacam-se as políticas de rotulagem de advertência frontal de nutrientes críticos à obesidade e DCNTs, a taxação de bebidas açucaradas e de outros alimentos ultraprocessados, a regulação da promoção e marketing desses alimentos, especialmente direcionados às crianças, e a restrição das vendas desses alimentos em escolas, locais de trabalho, hospitais ou outros serviços de saúde. Ressalta-se, ainda, que políticas de zoneamento, para garantir a presença de locais que comercializem alimentos saudáveis, o incentivo ao acesso a alimentos de pequenos produtores, e a criação de equipamentos públicos de abastecimento (ex. feiras de pequenos produtores) são ações necessárias para a democratização dos sistemas de comercialização a fim de propiciar o acesso a alimentos locais, saudáveis e diversos, ambientalmente e socialmente sustentáveis (Monteiro et al., 2019b; GNR, 2018; WHO, 2018a; Batis et al., 2016; Hawkes et al., 2015; Corvalán et al., 2013; Hawkes et al., 2013). Para tanto, políticas públicas de alimentação e nutrição são essenciais para articular estratégias a fim de melhorar as condições de alimentação, nutrição e saúde das populações. A Austrália, no entanto, não possui uma revisão de sua Política Nacional de Nutrição desde 1992 (PHAA, 2018).

A ampliação da autonomia dos sujeitos em suas escolhas alimentares perpassa a garantia do acesso a informações confiáveis e, nesse sentido, a abordagem do processamento de alimentos em estratégias de educação alimentar e nutricional e guia alimentares é fundamental. O Guia Alimentar para a população Australiana, publicado em 2013, recomenda limitar o consumo de *'discretionary foods'*, alimentos manufaturados pela indústria com baixa qualidade nutricional (NHMRC, 2013). Embora possivelmente grande parte destes alimentos são ultraprocessados, o processamento de alimentos não constitui a base para as recomendações do Guia, e alimentos ultraprocessados como pães, cereais matinais, iogurtes saborizados e margarina fazem parte dos cinco grupos de alimentos recomendados para o consumo (NHMRC, 2013).

Políticas públicas representam um compromisso dos governos com a sociedade, cuja construção deve ser participativa e compreender uma agenda que reflita os interesses da população e a efetivação de direitos sociais. Por esta razão, destaca-se, por fim, a importância de um posicionamento veemente contra o controle da agenda de nutrição por interesses comerciais da indústria de alimentos, com atenção às grandes corporações que atuam em escala global para cooptar formuladores de políticas públicas para que se oponham a qualquer tipo de regulamentação de suas atividades (Nestle, 2019; Steele et al., 2019; Moore et al., 2019; Townsend et al., 2019; Fabbri et al., 2018).

Combater todas as formas de má nutrição é o grande desafio enfrentado nesta geração (FAO, 2016b). Em países de alta renda, como a Austrália, o consumo de alimentos não saudáveis é o maior fator de risco para o desenvolvimento de doenças crônicas não transmissíveis (WHO, 2018b). Sabe-se que os sistemas alimentares hoje não propiciam dietas adequadas (WHO/FAO, 2018; Global Panel, 2016). Apenas políticas públicas baseadas em evidências coerentes aos problemas contemporâneos de nutrição e livres de conflitos de interesse serão capazes de transformar o sistema alimentar e conduzir a mudanças de comportamento em toda a sociedade.

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7 ANEXOS

Comprovante de aceite e submissão dos artigos

Decision Letter (bmjopen-2019-029544.R1)

From: info.bmjopen@bmj.com
To: priscilamachado@usp.br
CC:
Subject: BMJ Open - Decision on Manuscript ID bmjopen-2019-029544.R1
Body: 10-Jul-2019

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Identificação

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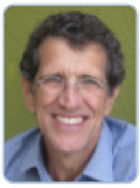
Endereço Profissional	Universidade de São Paulo, Faculdade de Saúde Pública. Faculdade de Saúde Pública Pacaembu 01246904 - São Paulo, SP - Brasil Telefone: (11) 30852329 URL da Homepage: http://www.fsp.usp.br

Formação acadêmica/titulação

2016	Doutorado em andamento em Nutrição em Saúde Pública. Faculdade de Saúde Pública da Universidade de São Paulo, FSP/USP, Brasil. com **período sanduíche** em The University of Melbourne (Orientador: Gyorgy Scrinis). Título: Consumo de alimentos ultraprocessados, perfil nutricional da dieta e obesidade em sete países. Estudo na população australiana, Orientador: Carlos Augusto Monteiro. Bolsista do(a): Fundação de Amparo à Pesquisa do Estado de São Paulo, FAPESP, Brasil. Palavras-chave: Consumo de alimentos; Dieta; Processamento de alimentos; Austrália. Grande área: Ciências da Saúde
2014 - 2016	Mestrado em Nutrição em Saúde Pública. Faculdade de Saúde Pública da Universidade de São Paulo, FSP/USP, Brasil. Título: Influência dos supermercados na disponibilidade e preço de alimentos ultraprocessados consumidos no Brasil,Ano de Obtenção: 2016. Orientador: Renata Bertazzi Levy. Bolsista do(a): Fundação de Amparo à Pesquisa do Estado de São Paulo, FAPESP, Brasil. Palavras-chave: Processamento de alimentos; Aquisição de alimentos; Custo; Demanda de alimentos; Varejo; Pesquisa de orçamentos familiares. Grande área: Ciências da Saúde Grande Área: Ciências da Saúde / Área: Saúde Coletiva / Subárea: Epidemiologia.
2009 - 2013	Graduação em Nutrição. Universidade Federal de Santa Catarina, UFSC, Brasil.

Formação Complementar

2018 - 2018	Advanced Skills for Sessional Teachers. (Carga horária: 6h). The University of Melbourne, UNIMELB, Austrália.
2017 - 2017	Análise Multinível. (Carga horária: 6h). Faculdade de Saúde Pública da Universidade de São Paulo, FSP/USP, Brasil.
2015 - 2015	Introdução ao uso do Software Stata. (Carga horária: 40h). Faculdade de Saúde Pública da Universidade de São Paulo, FSP/USP, Brasil.
2014 - 2014	Ciclo de Seminários do Programa de Aperfeiçoamento de Ensino. (Carga horária: 15h). Escola de Enfermagem da USP, EEUSP, Brasil.
2013 - 2013	



Carlos Augusto Monteiro

Bolsista de Produtividade em Pesquisa do CNPq - Nível 1A

Endereço para acessar este CV: http://lattes.cnpq.br/9217754427341680
Última atualização do currículo em 04/06/2019

A formação acadêmica do Professor Monteiro inclui graduação em Medicina, Residência e Mestrado em Medicina Preventiva, Doutorado em Saúde Pública, todos cursados na USP, e pós-doutorado no Instituto de Nutrição Humana da Columbia University. Sua carreira de pesquisador e orientador (já formou 12 mestres e 20 doutores) foi feita no Depto.de Nutrição da Faculdade de Saúde Pública da Universidade de São Paulo (USP), onde é Professor Titular desde 1989. Entre 1990 e 1992, trabalhou na Unidade de Nutrição da OMS em Genebra e foi professor visitante das universidades de Bonn e de Genebra. É coordenador científico do Núcleo de Pesquisas Epidemiológicas em Nutrição e Saúde da USP (NUPENS/USP) desde 1992. De dezenas de projetos de pesquisa realizados na área da Nutrição em Saúde Pública, resultaram vários livros e monografias e mais de 200 publicações indexadas na Web of Sciences com um total de mais de 10 mil citações (índice H: 50). É bolsista de produtividade científica do CNPq desde 1981 e pesquisador nível IA desde 1989. São destaques de sua produção científica voltada para o Brasil artigos sobre inquéritos populacionais em saúde e nutrição infantil realizados em São Paulo nas décadas de 70, 80 e 90, cujos resultados foram essenciais para redefinir o enfoque e o conteúdo dos programas nutricionais nas unidades básicas de saúde de São Paulo e, posteriormente, de todo o país; projeto temático interdisciplinar FAPESP de resgate e interpretação das tendências temporais das condições de saúde e nutrição da população brasileira na segunda metade do século XX, do qual resultou livro ganhador do prêmio Jabuti de melhor livro do ano na categoria Ciências Naturais e Medicina; análises das Pesquisas de Orçamentos Familiares do IBGE, que trouxeram nova e crítica visão para o problema da segurança alimentar no país; desenvolvimento e validação de um sistema nacional de monitoramento de fatores de risco para doenças crônicas baseado em entrevistas telefônicas, ganhador do Prêmio de Incentivo em Ciência e Tecnologia para o SUS de 2005 e inspirador do sistema VIGITEL implantado desde 2006 pelo Ministério da Saúde nas 26 capitais de estados brasileiros e Distrito Federal; estudos que documentaram o declínio excepcional da desnutrição infantil no Brasil entre 1996 e 2007 e quantificaram o papel da redução da pobreza e da extensão de cobertura de serviços públicos essenciais naquele declínio; e estudos sobre padrões de alimentação e saúde no Brasil, que orientaram a elaboração do Guia Alimentar para a População Brasileira 2014. Como parte de sua produção científica de impacto internacional, destacam-se estudos sobre determinantes da tendência secular do aleitamento materno e da mortalidade infantil em países em desenvolvimento; criação de novos indicadores para a avaliação antropométrica do estado nutricional de populações; estudos sobre o fenômeno da transição alimentar e nutricional nos países em desenvolvimento, desenvolvimento do sistema NOVA de classificação de alimentos, que se tornou referência mundial para a análise do efeito do processamento de alimentos na qualidade da dieta e na saúde humana e dezenas de estudos populacionais que demonstraram a associação entre o consumo de alimentos ultraprocessados e doenças crônicas não transmissíveis. É Editor Científico da Revista de Saúde Pública, é membro do Conselho Editorial da Public Health Nutrition e, desde 2010, integra, o comitê Nutrition Guidance Expert Advisory Group da OMS. Em 2010, foi o terceiro brasileiro a ganhar o prêmio Abraham Horwitz de Liderança Científica em Saúde nas Américas outorgado pela OPAS todos os anos ao pesquisador latinoamericano que mais se destacou no campo. É membro da Academia Brasileira de Ciências desde 2007. Em 2018, foi relacionado pela Web of Sciences/Clarivate?s Analytics entre os 1% dos cientistas da grande área das Ciências Sociais cujos artigos científicos alcançaram maior repercussão na literatura científica (2018 Highly Cited Researchers). **(Texto informado pelo autor)**

Identificação

Nome	Carlos Augusto Monteiro
Nome em citações bibliográficas	Monteiro CA ou Monteiro C;Monteiro, Carlos Augusto;Monteiro, Carlos A;Monteiro, Carlos;Monteiro, Carlos A.;MONTEIRO, C. A.;MONTEIRO, C.;Monteiro, C;MONTEIRO, CARLOS;Monteiro Carlos;Carlos