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EDITORIAL

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Contemporary syntheses in nutrition and dietetics

My last editorial, prepared for the February 2020 issue of Nutrition & Dietetics titled "A time of change",[1] described that we were in an era of accelerating change. In hindsight this observation was a serious underestimate, little did we know at that time of the massive change on so many levels that would arise from a global pandemic. We have experienced health, social, and economic disruption of an unimaginable magnitude. I acknowledge the outstanding work of dietitians and nutritionists internationally for their commitment to practice through this most challenging of times. Delivery of excellence in nutrition care throughout the health and aged care sectors via telehealth or face-to-face modes; facilitation of food systems through roles in industry, food services, and the food relief sector; and continued delivery of high-quality education and research in academia are just a few of the critical roles that dietitians and nutritionists have contributed throughout this intense period.

In parallel to the pandemic, the known challenges we face to the health and sustainability of our planet have not diminished. Recent high-level reports[2,3] declare that now is the time for action on sustainability and climate change. The Climate Change Performance Index[4] released for the 2021 COP26 summit in Glasgow applied a very low rating for Australia's performance across every index category: greenhouse gas emissions, renewable energy, energy use, and climate policy. Across all of these metrics, Australia can undoubtedly perform so much better. Effective public health strategies and climate mitigation are just some of the systemic actions required. Consideration of more sustainable agriculture, food (including energy needs, distribution, packaging, and waste management), and the utility of our broader food systems, sit right within scope as solutions to address the environmental challenges we face.

Hence why the Dietitians Australia position statement on healthy and sustainable diets[5] in this issue has been released at such a critical time for our profession. This substantial synthesis of the literature to answer three research questions recognises that the Indigenous peoples of our country have nurtured a sustainable food system for thousands of years. It highlights the remarkable contrast between the traditional ways and the globalised food system in which we now produce and procure food. The position statement is timely, with the recent release of the National Preventive Health Strategy 2021–2030,[6] the review of the Australian Dietary Guidelines currently underway, and an imminent Federal election. Explicit evidence-based recommendations have been made for the development of a National Food and Nutrition Strategy honouring Indigenous knowledge of food systems, integration of sustainability principles in the Australian Dietary Guidelines, reorientation of the food environment whereby access to healthy and sustainable foods is prioritised, and the need for investment in capacity building activities to equip the current and future nutrition and dietetics workforce regarding sustainability across the spectrum of the food system. Guidance for future research made within this position statement aligns with the views of national research experts where "implementation and evaluation research on initiatives that lead to more sustainable food systems" is a priority for dietetic research across this decade.[7] At a professional level, the position statement is also essential to guide the translation and implementation of the revised National Competency Standards for Dietitians.[8] Performance Criteria 1.3.7 "Identifies opportunities and advocates for change to the wider social, cultural and political environment to improve nutrition, food standards and the food system" within these Competency Standards clearly aligns with this position statement, hence it will support and guide advocacy work and practice on multiple fronts.

Other reviews within this issue synthesise topical practice issues in public health nutrition and dietetics. The scoping review prepared by Shi et al.[9] on the effects of the COVID-19 pandemic on food security in Australia further highlights some systemic problems within the food supply chain, but indeed considers other social issues that have emerged and been highlighted over the past 2 years. The review of Payne et al.[10] considers rural healthcare delivery and maternal and infant outcomes for diabetes in pregnancy, whilst the review led by Du et al.[11] examines the effects of macronutrient intake on sleep duration and quality.

In this issue, we publish a series of systematic reviews examining key clinical questions. These include understanding the efficacy and safety of biophenol-rich nutraceuticals in adults with inflammatory gastrointestinal diseases and irritable bowel syndrome,[12] exploring weight

management interventions that include dietary components for young people with chronic healthcare needs,[13] examining the scope of use of behaviour change theories and techniques used to inform nutrition interventions for adults undergoing bariatric surgery,[14] and seeking to understand the efficacy of early enteral nutrition versus total parenteral nutrition for patients with gastric cancer complicated with diabetes mellitus.[15] There are also two reviews that explore the effects of dining room interventions across a range of settings,[16] and meal choice in aged care where, regrettably, standards have not yet been explicitly defined.[17]

In addition to the reviews compiled within this issue, I await the release of other issues of Nutrition & Dietetics planned for 2022. Special themed issues have been curated with a focus on clinical nutrition, food and mental health, and professional issues in nutrition and dietetics. These will continue to be supported virtually for members of Dietitians Australia with our quarterly Research Bites presentations continuing this year. And, following on from our successful open call for papers for the special Methods issue in 2021, there is a current call open for papers for a Food Systems and Sustainability special issue.

Many more of our accepted papers will be published open access from 2022 supported by a new Council of Australian University Librarians (peak leadership organisation for university libraries in Australia) and Wiley Read & Publish agreement. Further information on this agreement can be accessed at https://caul.libguides.com/read-and-publish/wiley. I extend my thanks for the outstanding contributions in preparing all issues to the Editorial Board members, reviewers, and authors of papers published in this journal. Also, to the Dietitians Australia Board, who support the view that a strong evidence base is central to contemporary dietetic practice.

In closing, let us hope that change continues to occur; sustainable change and practices both at the micro and macro levels, and without the uncertainty and social upheaval we have experienced in recent times. The future of the food supply, healthcare systems, and planetary health are interdependent, and are reliant on sustainable choices, systems, and practices. We all have a role to play.

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REFERENCES

1. Porter J. A time of change. *Nutr Diet*. 2020;77:3-5.
2. Romanello M, McGushin A, di Napoli C, et al. The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. *Lancet*. 2021;398:1619-1662.
3. United Nations Framework Convention on Climate Change. Outcomes of the Glasgow Climate Change Conference—Advance Unedited Versions (AUVs) and list of submissions from the sessions in Glasgow. https://unfccc.int/process-and-meetings/conferences/glasgow-climate-change-conference-october-november-2021/outcomes-of-the-glasgow-climate-change-conference (2022). Accessed 6 Jan 2022.
4. Climate Change Performance Index 2022 Australia. https://ccpi.org/country/AUS/ (2021). Accessed 7 Jan 2022.
5. Barbour L, Bicknell E, Brimblecombe J, et al. Dietitians Australia position statement on healthy and sustainable diets. *Nutr Diet*. 2022;79:6-27.
6. Department of Health. National preventive health strategy 2021–2030. https://www.health.gov.au/resources/publications/national-preventive-health-strategy-2021-2030. Accessed 21 Dec 2021.
7. Porter J, Charlton C, Tapsell L, Truby H. Using the Delphi process to identify priorities for dietetic research in Australia 2020-2030. *Nutr Diet*. 2020;2020(77):437-443.
8. Dietitians Australia. National Competency Standards for Dietitians. https://dietitiansaustralia.org.au/maintaining-professional-standards/ncs/ (2021). Accessed 20 Dec 2021.
9. Louie S, Shi Y, Allman-Farinelli M. The effects of the COVID-19 pandemic on food security in Australia: a scoping review. *Nutr Diet*. 2022;79:28-47.
10. Payne E. Rural healthcare delivery and maternal and infant outcomes for diabetes in pregnancy: a systematic review. *Nutr Diet*. 2022;79:48-58.
11. Du C, Almotawa J, Feldpausch CE, Folk SYL, Parag H, Tucker RM. Effects of macronutrient intake on sleep duration and quality: a systematic review. *Nutr Diet*. 2022;79:59-75.
12. Giang J, Lan X, Crichton M, Marx W, Marshall S. Efficacy and safety of biophenol-rich nutraceuticals in adults with inflammatory gastrointestinal diseases or irritable bowel syndrome: a systematic literature review and meta-analysis. *Nutr Diet*. 2022;79:76-93.
13. Billich N, Maugeri I, Calligaro L, Truby H, Davidson ZE. Weight management interventions that include dietary components for young people with chronic health care needs: a systematic review. *Nutr Diet*. 2022;79:94-109.
14. Wright C, Barnett A, Campbell KL, Kelly JT, Hamilton K. Behaviour change theories and techniques used to inform nutrition interventions for adults undergoing bariatric surgery: a systematic review. *Nutr Diet*. 2022;79:110-128.
15. Li K, Wang D, Zhang X, Yang J, Chen X. Efficacy of early enteral nutrition versus total parenteral nutrition for patients with gastric cancer complicated with diabetes mellitus: a meta-analysis. *Nutr Diet*. 2022;79:129-139.
16. McLaren-Hedwards T, D'cunha K, Elder-Robinson E, et al. Effect of communal dining and dining room enhancement interventions on nutritional, clinical and functional outcomes of patients in acute and sub-acute hospital, rehabilitation and aged-care settings: a systematic review. *Nutr Diet*. 2022;79:140-168.
17. Wheeler M, Abbey KL, Capra SM. Meal choice for residential aged care is not yet defined: a scoping review of policies, standards, reports and guidelines. *Nutr Diet*. 2022;79:169-180.

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POSITION PAPER

Dietitians Australia position statement on healthy and sustainable diets

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Abstract

It is the position of Dietitians Australia that to promote human and planetary health, a food system transformation is needed that enables the population to adopt healthy and sustainable diet-related practices. A healthy and sustainable diet must (i) be nutritionally adequate, healthy and safe, (ii) have low environmental impact and be protective of natural resources and biodiversity, (iii) be culturally acceptable and (iv) be accessible, economically fair and affordable. Dietitians Australia acknowledges that it is critical to prioritise Indigenous knowledges in consultation, policy-making and implementation processes to achieve these recommendations. In facilitating the uptake of healthy and sustainable diets, dietitians are contributing to the transformation of our current food system that is urgently required to nourish present and future generations within planetary boundaries. In developing this position statement, opportunities for future research have been identified including those to advance the professions' capacity to improve environmental sustainability outcomes across all areas of practice. To achieve a population-level shift towards this diet, Dietitians Australia recommends: (i) the development of a National Food and Nutrition Strategy which honours Indigenous knowledges on food systems, (ii) the integration of sustainability principles in Australia's dietary guidelines, (iii) the reorientation of our food environment to prioritise access to healthy and sustainable foods, and (iv) investment in capacity building activities to equip the current and future nutrition and dietetics workforce.

KEYWORDS

diet, environmental sustainability, planetary health, public health nutrition

Authors are members of the Dietitians Australia Healthy and Sustainable Diets Working Group.

1 | BACKGROUND

Indigenous peoples of the world have managed sustainable food systems for millennia, providing food, livelihoods and well-being to humankind.[1] Indigenous people's food systems are founded on values of reciprocity and respect for the whole ecosystem, whereby humans are interconnected with the natural environment. The way food is produced and consumed has changed drastically over recent decades and disregards Indigenous knowledge of human–ecology interaction and its balance.[2,3] As we attempt to mitigate the effects of climate change and an increasing prevalence of diet-related disease, Indigenous peoples' knowledges of sustainable food systems can provide insights, lessons and evidence.[1,4] It is believed that 'the world cannot feed itself sustainably without listening to Indigenous peoples'.[1,p.10] However, many would argue that to promote human and planetary health, the global community must go beyond listening and demonstrate a deep respect for Indigenous peoples as the custodians and expert stewards of the land, waterways and our finely balanced ecosystem.

The relationship between our climate and our food system is bidirectional. On one side, climate change is affecting our planet's ability to produce food under extreme weather conditions, diminishing natural resources, ocean acidification and rising sea levels.[5,6] On the other side, our food system disrupts natural ecosystems by creating more greenhouse gas emissions than any other single contributor, causing land degradation, depleting water stores and driving biodiversity loss.[7,8] While food systems have the potential to promote human health, environmental sustainability and equity, they are currently threatening all three.[2] Poor quality diets remain the leading preventable risk factor for chronic disease, particularly amongst lower socio-economic groups where inequities in access to resources prevail.[9,10] Despite evidence that global food production has kept pace with population growth in terms of dietary energy requirements, over 820 million people have insufficient food.[2] The current food system is failing on both counts.

In Australia, the way our food is produced, manufactured, distributed and consumed is contributing to climate change and malnutrition in all its forms.[10,11] Our agricultural sector is responsible for 16% of Australia's greenhouse gas emissions as well as biodiversity loss, water consumption and unsustainable land management practices.[12] Our dietary consumption patterns yield the highest per capita greenhouse gas emissions of all the G20 countries.[13] If the global population were to adopt Australian consumption patterns, by 2050 the natural resources of over six and a half Earths would be required to support food production.[13] This is only worsened by the fact that foods which are energy-dense and nutrient-poor account for 27% of diet-related emissions.[14–16] These discretionary products (foods high in fat, sugar and/or salt) contribute 38% of the energy purchased from food and drinks from supermarkets in Australia.[17] Our food system is also a key contributor to chronic disease risk. Australia and New Zealand have the highest rates of childhood overweight at 16.9%, compared to a global average of 5.7%, and the highest rates of adult obesity at 30.7%, compared to a global average of 13.2%.[18] Despite being considered 'the lucky country', 12.3% of Australia's population is experiencing food insecurity compared to a 7.6% average amongst other high income countries.[18] When comparing Australia's food system scorecard to those in the global arena, it is clear that urgent action is required to contribute to global transformative efforts.

While the challenges to achieve such bold action are significant, efforts to improve our food system can have far-reaching benefits such as improving food security and nutrition, social and gender equity, and community resilience, amongst others.[19] In 2019, the EAT-Lancet Commission advised that 'nothing less than a Great Food Transformation' is required, including a global shift towards healthy and sustainable diets.[2] This transformation requires cross-sectoral, global collaboration. Global targets exist to support Australia's effort to achieve this population-wide dietary shift, including Agenda 2030 and the Paris Agreement, which are proving to be effective mechanisms for attracting political will and driving change.[20–22] The United Nations' Decade of Action on Nutrition commits United Nations' Member States, including Australia, to implement public health policy to create sustainable, resilient food systems for healthy diets for all.[23] It is agreed that a whole-of-system approach is required, as evidenced by Indigenous food systems which sustained biodiversity, natural resources and an abundance of food sources in both land and water-based ecosystems.[24] Broadly defined, the food system 'encapsulates the activities, outcomes and actors involved in agriculture, storage, processing and manufacture, distribution, retail and consumption'.[25,p.1097] The points of intersection between diet and this broader food system present opportunities to achieve systemic transformation, whereby efforts to promote the consumption of healthy and sustainable diets can trigger transformative action across the entire food system.[19,26–28]

Dietitians utilise scientific principles and methods in the study of nutrition, to influence the wider food environment and ultimately affect food intake and eating behaviour.[29] Dietitians therefore have a key role to play in contributing to food system transformation, in particular by facilitating a population-wide shift to healthy and sustainable diets. Role statements developed in Australia

and overseas describe opportunities for dietetic practice to achieve this within various settings and levels of public policy.[30,31] For example in food-based dietary guidelines at the population-level, food procurement and menu planning policies at an institutional-level, product reformulation within the private food industry, nutrition education to client groups, community groups and other health professionals, and medical nutrition therapy at the group and individual level.[32] This paper presents Dietitians Australia's position on healthy and sustainable diets based on a review of existing literature. Using this evidence, key recommendations are provided to guide future research, practice and advocacy efforts, including an investment in capacity building activities and tertiary education to further equip Australia's current and future dietetic profession to contribute to food system transformation.

2 | METHODS

Exploration of existing literature was guided by a scoping review methodology. This approach was deemed suitable given the diverse and largely heterogenous literature available to answer the broad and complex research questions.[33] While guidance was taken from the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR), not all checklist items were feasible for this current study.[34] The following five-stage approach for scoping reviews was undertaken.[35–37]

2.1 | Stage 1: Identifying the research questions

To present an overview of existing evidence on healthy and sustainable diets, with the purpose of informing Dietitians Australia's policy recommendations, three research questions were developed by the expert working group: (i) What are the characteristics of healthy and sustainable diets? (ii) What approaches are being taken by researchers to measure health and environmental sustainability outcomes of population diets? (iii) What evidence-based policy options exist to facilitate the uptake of healthy and sustainable diets in Australia?

2.2 | Stage 2: Identifying relevant studies for inclusion

Searches were designed and conducted for each of these research questions respectively, drawing from both peer-reviewed and grey literature (Data S1: Search Strategies). It was deemed essential to include grey literature, particularly for the third research question, to ensure policy documentation was considered. Incognito mode was utilised for all Google Scholar searches to ensure replicability. To restrict the size of this study, literature published in English during a defined time period as outlined in the search strategies (Data S1) was retrieved and screened against the below inclusion criteria (Tables 1–3).

2.3 | Stage 3: Selection of included studies

Titles and abstracts, or in the case of Google Scholar the titles and introductory text of the first 100 results,[38] were screened by two researchers independently. Discrepancies were discussed and resolved by these two researchers before the identified full text papers were retrieved and assessed against the inclusion criteria (Data S1: PRISMA Flow Charts).

The final included studies were complemented by literature identified through both (i) reference lists of included studies, and (ii) by members of the expert working group, 'Dietitians Australia's Healthy and Sustainable Diets Position Statement Working Group'. These complementary sources of grey and peer-reviewed literature were identified by expert working group members from organisational newsletters, resource repositories (e.g. Food and Agriculture Organization's Global-Hub on Indigenous Peoples' Food Systems: www.fao.org/indigenous-peoples/global-hub/en, Table: www.tabledebates.org, International Confederation of Dietetic Associations' Food Sustainability Toolkit: www.icdasustainability.org), public seminars and forums on the

TABLE 1 Inclusion criteria for Research Question 1

Criterion	Definition
Subject	The study must have been considered relevant to both healthy and sustainable diets. Studies were excluded if they only considered one of nutrition/health or ecology/environment.
Outcome	The study must have included a description of at least one newly defined characteristic of a healthy and sustainable diet, or a *statement/concept* relevant to the definition of healthy and sustainable diets.
Study	The publication must have been available in English, published on or after 2012, included adequate detail to discern relevance. Study type – any peer-reviewed publication (Google Scholar) and systematic literature reviews (PubMed) were considered.

TABLE 2 Inclusion criteria for Research Question 2

Criterion	Definition
Subject	The study must have been considered relevant to both healthy and sustainable diets. Studies were excluded if they only considered one of nutrition/health or ecology/environment.
Outcome	The study must have reported upon the impact of healthy and sustainable diets, and described the approaches or metrics used to measure this impact. Hypothetical scenarios such as simulation or modelling were included.
Study	The publication must have been available in English, published on or after 2019, included adequate detail to discern relevance. Study type – any peer-reviewed publication (Google Scholar) and systematic literature reviews (PubMed) were considered.

TABLE 3 Inclusion criteria for Research Question 3

Criterion	Definition
Subject	The study must have been considered relevant to both healthy and sustainable diets. Studies were excluded if they only considered one of nutrition/health or ecology/environment.
Intervention	The study must have described a policy (plan, action, intervention, initiative, activity or strategy), ideally with pre-determined intentions (goals, objectives, targets) accompanied by a planned approach or work plan to achieve or measure the desired outcome. Ad hoc activities were included, provided they were part of a broader policy.
Setting	Any policy/intervention setting was considered – all levels of government, all institutional settings, etc.
Population	Consumers or nutrition and dietetics professionals
Study	The publication must have been available in English, published on or after 2015, included adequate detail to discern relevance. Study type – any peer-reviewed publication (Google Scholar) and systematic literature reviews (PubMed) were considered. Hypothetical scenarios such as simulation or modelling were not included.

topic of healthy and sustainable diets and other dietetic associations' public positions on the topic such as Dietitians of Canada[30,39] and the Academy of Nutrition and Dietetics (formerly American Dietetic Association).[40] Records identified by working group members were categorised as either grey literature or those published in a peer-reviewed journal.

2.4 | Stages 4 and 5: Charting the data, summarising and reporting the results

Three approaches were adopted to present the results of each research question:

1. Research Question 1: To present the characteristics of healthy and sustainable diets, a summary of the published ideas, definitions and concepts from included studies was charted as a timeline in sequential order.
2. Research Question 2: To explore the approaches taken to measure the outcomes of healthy and sustainable diets, results from included studies were synthesised and described according to the four elements of a healthy and sustainable diet as proposed by the Food and Agriculture Organization.[41] As some included studies used approaches such as modelling to measure more than one of these four elements simultaneously, an additional category was created.
3. Research Question 3: To explore policy options available to promote the uptake of healthy and sustainable diets in Australia, three reporting methods were adopted. Firstly, a brief summary was written, using examples drawn from retrieved studies. Secondly a table of specific policy examples derived from the included studies was presented, categorised according to the facilitating setting; federal government, local government, food industry and institutional. Thirdly, an overview of policy options was organised according to the NOURISHING Framework.[42] This framework was chosen as it is intended to organise comprehensive policy options across three domains – food environment, food system and behaviour change – to promote healthier eating.[42]

A key objective of this study was to present Dietitians Australia with key recommendations to facilitate the population-wide uptake of healthy and sustainable diets. The recommendations were first drafted by the expert working group (authors of this paper), based on the evidence presented to answer each of this study's research questions, and Dietitians Australia's capacity to influence policy across the diverse settings. The four recommendations were reviewed by Dietitians Australia's Food and Environment interest group leadership committee, Dietitians Australia's Advocacy and Policy Advisory Committee and finally Dietitians Australia's Board of Directors to produce the position statement outlined in this manuscript.

TABLE 4 Key published ideas and concepts to define a healthy and sustainable diet

Author	Publication title	Definition
Burlingame et al.[41]	Sustainable diets and biodiversity	This landmark definition was published in the Proceedings of the International Scientific Symposium on Biodiversity and Sustainable Diets United Against Hunger, held in Rome at FAO's Headquarters in November 2010. This symposium provided experts with a platform to reach the following consensus definition: 'Sustainable Diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimising natural and human resources.'[41,p.7] This definition continues to be referred to, for example in FAO's (2021) report and white paper on Indigenous peoples' food systems.[1,24]
Friel et al.[48]	Towards healthy and sustainable food consumption: an Australian case study	Friel et al. synthesised publicly available evidence on the environmental impact of diets and defined 'three over-arching principles: (i) any food that is consumed above a person's energy requirement represents an avoidable environmental burden in the form of greenhouse gas emissions, use of natural resources and pressure on biodiversity; (ii) reducing the consumption of discretionary food choices, which are energy-dense and highly processed and packaged, reduces both the risk of dietary imbalances and the use of environmental resources; and (iii) a diet comprising less animal- and more plant-derived foods delivers both health and ecological benefits.'[1,24,48,p.1159] Based on these, they constructed a weekly healthy and sustainable food basket, as a method with which to assess the availability and affordability of a healthy and sustainable diet.
Johnston et al.[49]	Understanding sustainable diets	Johnston et al. contribute a descriptive analysis of the determinants and processes that influence diets and their impact on health, food security and environmental sustainability. They identify five categories which determine the *sustainability* of a diet: (i) agriculture, (ii) health, (iii) sociocultural, (iv) environmental, and (v) socioeconomic.
Nelson et al.[50]	Alignment of healthy dietary patterns and environmental sustainability: a systematic review	Nelson et al. updated the systematic review conducted by the 2015 Dietary Guidelines Advisory Committee. Adding to the original 15 studies, an additional eight studies were analysed to conclude that 'a dietary pattern higher in plant-based foods (e.g., vegetables, fruits, legumes, seeds, nuts, whole grains) and lower in animal-based foods (especially red meat), as well as lower in total energy, is both healthier and associated with a lesser impact on the environment'.[50,p.1005] This was consistent with several well-categorised dietary patterns, including vegetarian diets, US dietary guidelines-related diets, Mediterranean-style diets and the Dietary Approaches to Stop Hypertension (DASH) diet.
Von Koerber et al.[51]	Wholesome nutrition: an example for a sustainable diet	Von Koerber et al. described the concept of *Wholesome Nutrition* as it was developed in the 1980s in alignment with health, ecological, economic, social and cultural dimensions of nutrition. They analysed the food supply chain at all stages from production to waste disposal and identified seven principles of sustainable nutrition: (i) preference of plant-based foods, (ii) organic foods, (iii) regional and seasonal products, (iv) preference of minimally processed foods, (v) fair trade products, (vi) resource-saving housekeeping, and (vii) enjoyable eating culture.

TABLE 4 (Continued)

Author	Publication title	Definition
Monteiro et al.[52]	The United Nations Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing	This commentary piece introduced the NOVA system of food classification, which categorises all food into four groups, based on the nature, extent and purpose of food processing. Group 1: unprocessed or minimally processed foods (e.g. seeds, fruits, leaves, stems, eggs, milk). Group 2: processed culinary ingredients (e.g. oils, butter, sugar, salt). Group 3: processed foods (e.g. bottled vegetables, canned fish, fruits in syrup, cheese, bread). Group 4: ultra-processed foods (e.g. soft drinks, sweet or savoury packaged snacks, reconstituted meat products, pre-prepared frozen dishes). Monteiro et al. (2018) described the rapidly increasing production of ultra-processed products, which contribute to climate disruption, pollution, degradation and depletion of air, land, water and sources of energy, as a world crisis to be addressed as part of the United Nation's Sustainable Development Goals.
World Health Organization (WHO)[53]	A healthy diet sustainably produced (information sheet)	WHO identified that to ensure a healthy diet for current and future populations, we must 'focus on the most vulnerable populations, on promoting a healthy and diverse diet and on changing to sustainable food production systems'.[53,p.3] WHO presented 14 recommendations for a healthy diet that is sustainably produced, which are applicable to low-, middle- and high-income country settings with consideration of health, environmental, gender, and equity outcomes.
EAT Lancet Commission[2]	Food planet health—summary report	The EAT Lancet Commission defined the planetary health diet as a means to nourish a population of 10 billion people by 2050 while respecting planetary boundaries. This *flexitarian diet* is 'largely plant-based but can optionally include modest amounts of fish, meat and dairy foods.'[53,p.32,p.11] The EAT-Lancet Commission defined scientific targets for a planetary health diet for an intake of 1500 kcal/day however encourage local interpretation to reflect the culture, geography and demography of the population and individuals.
Smetana et al.[54]	A path from sustainable nutrition to nutritional sustainability of complex food systems	Smetana et al. describe *Nutritional Sustainability* as a concept which 'sets environmental sustaining capacity as a baseline level for balanced nutrition' while also aiming for the 'search of food system driving nodes'.[54,p.39] *Nutrition Sustainability* does not aim for the support of solutions of producing enough or more food for increasing population (*sustainable nutrition*), neither does it contradict other similar concepts [*sustainable nutrition security*, *nutritional life cycle assessment (LCA)*].[54]
Lawrence et al.[55]	Sustainable, resilient food systems for healthy diets: the transformation agenda	Lawrence et al. commented on the EAT Lancet Commission's planetary health diet by summarising the recommendations, commending the comprehensive approach taken and outlining the response amongst key stakeholders. Some criticisms presented which are of relevance to defining healthy and sustainable diets are those concerning nutritional adequacy for population subgroups such as pregnant women, the feasibility of uptake given the flexitarian diet is largely prescriptive and the omission of ultra-processed foods in their analysis.
FAO and WHO[56]	Sustainable healthy diets – guiding principles	This document resulted from an international expert consultation to develop guiding principles for sustainable healthy dietary patterns to be translated into policy action. Five background papers were prepared by global experts in advance of a three-day consultation in Rome. They defined sustainable healthy diets as those which 'achieve optimal growth and development of all individuals and support functioning and physical, mental, and social wellbeing at all life stages for present and future generations: contribute to preventing all forms of malnutrition (i.e. undernutrition, micronutrient deficiency,

(Continues)

TABLE 4 (Continued)

Author	Publication title	Definition
		overweight and obesity); reduce the risk of diet-related non-communicable diseases; and support the preservation of biodiversity and planetary health.'[56,p.11] There are 16 guiding principles which relate to the health, environment and sociocultural aspect of sustainable healthy diets.
Kuhnlein et al.[57]	Indigenous food systems: contributions to sustainable food systems and sustainable diets. In Burlingame B. and Dernini S., Sustainable Diets. Linking Nutrition and Food Systems.	Kuhnlein et al. describe that Indigenous peoples' have 'a collective experience in managing 22% of the world's ecosystem and land mass and preserving the majority of the planet's biodiversity. Indigenous peoples understand how their local foods are resilient and adapted to their local environments, even when climate challenged. They know the animals and plants that are natural resources in the world's forests, pastures, riverine lands and waters, lakes, and seas, which contain the genetic material of the world's biodiversity. The knowledge of these resources is grounded in their culture, spirituality and historical legacy. Those who can relate and express such knowledge can help the world to develop, realise and enjoy the benefits of Indigenous food systems, which are essential for sustainable diets', whilst safe-guarding the rights of Indigenous peoples.[57,p.67]
Barbour et al.[58]	Translating evidence into policy action: which diet-related practices are essential to achieve healthy and sustainable food system transformation?	Barbour et al. sought to define healthy and sustainable diet-related practices that could be targeted by policy-makers. These diet-related practices were defined as the activities that an individual engages in to source, store, prepare, consume and dispose of food. A review of relevant United Nations' publications dated after FAO's (2012) landmark definition, distilled 13 commonly recommended healthy and sustainable diet-related practices: (i) select food grown using sustainable food production practices, valuing and respecting Indigenous knowledges, (ii) strengthen local food systems by connecting with primary producers, (iii) eat seasonally, incorporating native and wild-harvested foods, (iv) eat locally available foods, (v) avoid over-consumption beyond energy requirement, (vi) consume no more than recommended animal-derived foods, (vii) limit intake of ultra-processed, nutrient-poor and over-packaged food, (viii) increase intake of plant-based foods, (ix) eat a wide variety of foods to promote biodiversity, (x) adopt food waste-minimisation strategies, (xi) preference home-made meals and share with others, (xii) consume safe tap water as preferred drink, and (xiii) breastfeed infants where possible.

3 | RESULTS

3.1 | What are the characteristics of healthy and sustainable diets?

To achieve population-level shifts towards healthy and sustainable diets, the characteristics of the desired dietary behaviours must be clearly defined. The concept of healthy and sustainable diets is not new. At the time that the view of food and health had become medicalised, Gussow and Clancy proposed that nutrition education must be extended beyond a medical view to incorporate the impact that people's food choices were having on the environment, and therefore on the nutrition of future generations.[43] In recent years, as the threat of climate change on food production and planetary health has gained attention, the topic of healthy and sustainable diets has created momentum amongst researchers and agencies of the United Nations. There has also been a shift in focus away from working with individuals on their dietary decision-making processes, towards efforts which create a food system that enables healthier food options and eating patterns as the default.[44] There is an increased appreciation of Indigenous peoples' food systems and knowledge required to maintain a balance between human–ecological interactions.[24] It is also

understood that not all healthy diets have low environmental impacts, and not all environmentally beneficial diets maximise human health.[19,45–47] Therefore, to understand the way in which a more comprehensive understanding of healthy and sustainable diets has been developed, Table 4 presents a timeline of key ideas and concepts which have been published and with direct relevance to an Australian context.

Scholars with expertise in healthy and sustainable food systems agree that 'no single exemplar diet exists'.[45, p.132] However, as outlined in Table 4, contributions to defining a healthy and sustainable diet have remained consistent with the FAO's (2012) original definition in that four elements must exist; a healthy and sustainable diet must (i) be nutritionally adequate, healthy and safe, (ii) have low environmental impact and be protective of natural resources and biodiversity, (iii) be culturally acceptable and (iv) be accessible, economically fair and affordable.[45]

3.2 | What approaches are being taken by researchers to measure health and environmental sustainability outcomes of population diets?

To assess the quality of population diets against these four elements of a healthy and sustainable diet, scholars have adopted a range of methods, such as modelling, life cycle assessment, and land use analysis and applied multiple disciplinary lenses.[50] Before presenting the approaches taken by scholars within the peer-reviewed literature, it must be acknowledged that Indigenous peoples' food systems have sustained life since millennia based on 'keen [detailed, complex and sustained] observations of the processes and effects of nature',[24,p.6] that may not yet be evident in the conventional hierarchies of scientific evidence.[59]

In looking at the first element, *the nutritional adequacy, health and safety of a diet*, Kumanyika et al. compared three approaches to measuring the healthiness of diets to inform the expert consultation on Sustainable Healthy Diets; WHO dietary guidelines, Global Burden of Disease risk factors and analysis of whole dietary patterns with health outcomes in population studies and clinical trials.[60] Although interested solely in health outcomes, they identified crucial win–win opportunities to promote healthy and sustainable diets by increasing plant-based foods, reducing processed meats, limiting the intake of salt, free sugars, saturated fats, trans fats and industrially processed foods.[60] Another approach to assess the nutritional quality of population-level diets is the NOVA classification system referred to in Table 4.[61] Nine systematic reviews have synthesised a substantial body of evidence reporting associations between ultra-processed foods and a range of adverse health outcomes.[62–70] Machado et al. found a positive linear trend between high intake of ultra-processed foods and high intake of nutrients linked to non-communicable diseases amongst Australian adults.[71] Ultra-processed foods have also been shown to have an association with adverse sustainability outcomes.[72]

In considering the second element, *environmental impact of a diet*, an integrative review of the metrics in use identified that journal literature mostly addressed greenhouse gas emissions and, to a lesser extent, land and water use.[73] This review identified that soil carbon stocks were overlooked as an important indicator of environmental impact.[73] This represents a misalignment in the scientific methodologies between publications aiming to inform climate action through agricultural production and those assessing the environmental impacts of foods to define a healthy and sustainable diet.[73] Chai et al. conducted a systematic review to compare vegan, vegetarian and omnivorous diets for their environmental impact.[74] They measured the environmental impact based on greenhouse gas emissions, land use and water footprint.[74] Focusing on the Swedish population diet, Mehlig et al. examined the changes in diet-related greenhouse gas emissions since the turn of the century, demonstrating the use of this single measure of sustainability to provide insights to a trend over time.[75]

Moving to Australian research on this environmental impact element, Ridoutt et al. quantified the water scarcity footprint of 9341 Australian adults using dietary intake data and compared this to the planetary boundary for freshwater use.[16] They concluded that diets based on Australia's dietary guidelines are within the planetary boundary for freshwater.[16] Using the same dietary intake data, Ridoutt et al. also investigated use of a weighted environmental impact score, factoring in climate footprint, water-scarcity footprint and cropland-scarcity footprint. Upon considering wider impacts, they concluded that a diet based on Australia's dietary guidelines could achieve a lower environmental impact score, but not low enough to achieve planetary boundary targets due to the impacts of the food production system.[76] Forbes et al. conducted a rapid review to determine the environmental impacts associated with food consumption in Australia and New Zealand and of the 20 studies included, greenhouse gas emissions (*n 12*) were the most commonly used environmental indicator followed by water use and environmental footprint (*n 7*) and carbon footprint (*n 3*).[77] Shamsi et al. explore the rich legacy of Aboriginal fishing cultures in Australia, offering valuable lessons to

conserve aquatic resources and understand human–ecology interconnectedness.[78] Their literature review describes examples of fishing practices, ideology and sustainable philosophy, such as only taking enough fish to nourish individuals and communities, and restricting fishing based on seasons and stock abundance, explaining how these are measured.[78]

To assess the *cultural acceptability of a diet*, Hachem et al. reviewed the contribution of two territorial diets, the Mediterranean and New Nordic diets, towards environmental, sociocultural and economic sustainability outcomes, arguing that some territorial or 'regional' diets can be a catalyst for food systems transformation.[79] Although not technically assessing the cultural acceptability, various socio-cultural drivers have likely contributed to the increased intake of ultra-processed foods.[80] For example, Baker et al. suggest that inequitable gender distribution of household work including shopping for and preparing family meals, may explain the higher proportions of semi-prepared, ready to eat ultra-processed meals and snacks consumed in Australia and other high-income countries.[80]

And finally, in assessing the *economic accessibility and affordability of a diet*, the use of a hypothetical food basket is a commonly used method to assess and monitor food availability and cost internationally and within Australia.[81–83] In measuring the affordability of a healthy and sustainable diet in Australia, Barosh et al. compared the price of a typical food basket with a healthy and sustainable food basket within five neighbourhoods of Greater Western Sydney.[48,84] They concluded that those most economically disadvantaged, both at a neighbourhood and household level, experience the greatest inequality in affordability of the healthy and sustainable diet. More recently, Goulding et al. compared an Australian-specific planetary health diet basket modelled on the EAT-Lancet Commission's recommended diet, to the typical Australian diet basket for two adults and two children.[85] Analysing the cost of each basket in low, medium and high socio-economic areas in each Australian state and territory identified that the Planetary Health Diet was more affordable for Australians living in Metropolitan areas than the typical Australian diet.[85] In another approach to measure the affordability of a healthy and sustainable diet, Donati et al. assessed dietary intake data from 104 young adults in Italy to identify two diets; the minimum cost healthy diet and the most environmentally sustainable diet (based on carbon emissions, water consumption and land use).[86] They then integrated both economic and environmental objectives to define a healthy, sustainable and affordable diet for this population group.[86]

To assess multiple outcomes of a population diet simultaneously, benchmark modelling has been shown to be useful, whereby pre-determined diets are evaluated against indices to quantify health, environment and affordability outcomes. For example, Mertens et al., compared a diet which adhered to food-based dietary guidelines in Denmark, Czech Republic, Italy and France and evaluated these according to their nutritional adequacy using the Nutrient Rich Diet score and their greenhouse gas emissions.[87] Their modelling measured three preferential diet scenarios; dietary preferences, nutrient quality and environmental impact and they concluded that fully maximising health and minimising greenhouse gas emissions cannot be achieved simultaneously.[87] Chen et al. conducted a multi-dimension, multi-indicator analysis involving nine alternative dietary scenarios, three nutritional quality scores, five environmental indicators, one economic measure and one human health indicator.[88] They concluded that transition towards a healthy diet (dietary guidelines of Swiss Society for Nutrition) was the most sustainable option and would result in 36% lesser environmental footprint, 33% lesser expenditure and 2.67% lower adverse health outcome (DALYs) compared with the current diet.[88]

Wrieden et al. developed a framework to quantify health, affordability and environmental sustainability measures for food purchase survey data in the United Kingdom.[89] They applied a life cycle assessment approach to detailed food composition data, measuring greenhouse gas emission, land use, diet quality (based on dietary guidelines and food cost), all standardised according to household income.[89] Allen et al. adopted a Delphi survey to propose a new metric system (with 18 indicators) to assess the sustainability of food systems and diets, specific to the Mediterranean area.[90] They also considered affordability and health in their sustainability assessment.[90] Clark et al. measured five health outcomes (type 2 diabetes, stroke, coronary heart disease, colorectal cancer and mortality, and five environmental outcomes: greenhouse gas emissions, land use, scarcity-weighted water use, acidification and eutrophication) to conclude that dietary transitions towards healthy food consumption will generally also improve sustainability.[91]

Springmann et al. conducted a modelling study to assess the healthiness and sustainability of national and global food based dietary guidelines of 85 countries.[92] They concluded that adoption of the EAT-Lancet's planetary health diet as compared to the WHO's dietary guidelines would achieve a 34% reduction in premature mortality and reduce greenhouse gas emissions by more than three times.[92] Of the 85 countries' dietary guidelines assessed, most (67%–87%) were incompatible with meeting targets set within the Paris Climate Agreement.[92] Hence, to achieve ambitious targets set to nourish a

growing global population within planetary boundaries, national dietary guidelines must be both healthier and more sustainable. Springmann's earlier work was analysed as part of a systematic review by Jarmul et al. which assessed the available published evidence on the effect of 'sustainable diets' (typically high in plant-sourced and low in animal-sourced and processed foods) on environmental footprints and human health.[93] Analysis of 18 studies was conducted using six environmental outcomes and seven health outcomes, which consistently placed a 'sustainable diet' as having both positive health effects and reduced environmental footprints with the exception of increased water use.[93] They discuss the consideration that co-benefits are not universal, with trade-offs required across the health and environmental measures even when population diets are carefully designed, evidence based and adapted to contextual factors.[93] Bunge et al. conducted a systematic review to explore the existing food profiling models as a tool to inform the development of food labels that account for nutrition and environmental sustainability.[94] Published in the Lancet Planetary Health, their review identified 16 sustainable food profiling models from which they describe a number of advantages and disadvantages.[75] Amongst the disadvantages, few profiling models to date account for at least two environmental impact factors and even less included other dimensions of sustainability or nutrition measures.[75]

Within an Australian context, Hendrie et al. modelled the average adult diet against dietary patterns consistent with Australia's dietary guidelines and identified that a 25% reduction in greenhouse gas emissions would result if our population were to follow existing guidelines.[15,46] Also modelling Australian dietary patterns, Candy et al. compared a *healthy mixed diet*, with both animal and plant foods, to a *healthy plant-based diet, with only p*lant foods.[95] Both diets met Australian dietary guidelines and four sustainability principles; avoiding over-consumption, reducing intake of discretionary foods, reducing animal products, and reducing food waste.[95] Modelled outcomes included food availability, water use, land use, greenhouse gas emissions, fuel and energy use and fertiliser use, and identified that a population-wide shift towards the plant-based diet would be associated with less environmental impact, however fertiliser use and land availability concerns would need to be addressed.[95]

As described, various approaches exist to measure the health and environmental outcomes of healthy and sustainable population diets. Madzorera et al. highlighted a number of challenges for researchers and practitioners working to measure healthy and sustainable diets, including the lack of standardisation and validation of diet quality (health and sustainability metrics) for countries globally.[96] They acknowledged that metrics must also consider convenience, preference and desirability which influence food choices.[96] In summary, further research and development of diet-related heath and sustainability metrics is required. These metrics must consider all four elements of FAO's (2012) definition of a healthy and sustainable diet to support effective measurement and population-wide uptake of this diet.

3.3 | What evidence-based policy options exist to facilitate the uptake of healthy and sustainable diets in Australia?

Having described progress to define what a healthy and sustainable diet is and how it is measured, this section explores approaches to facilitate the uptake of these diets in Australia. Peer-reviewed literature continues to emerge, demonstrating both the effectiveness and feasibility of various approaches. Bene et al.[97] defined five areas of research and action required to operationalise the EAT-Lancet Commission's recommendations; economic viability (e.g. discounts for low-income households to purchase fruits and vegetables), political economy (e.g. accountability mechanisms to 'fame and shame' actions taken by powerful food actors), cultural norms (e.g. guiding consumer behaviour by altering the choice architecture of the food environment), equity (e.g. full supply chain traceability to discourage child labour), governance and tools (e.g. use of foresight techniques to inform policy and decision-making).[97] Parsons and Hawkes sought to identify food systems policy with the co-benefits of healthy, environmental and economic policy goals in the United Kingdom.[98] They identified six aspects of food systems that show potential for all three outcomes to come together; public procurement, a Common Agricultural Policy, school fruit and vegetable schemes, investing in small and medium-sized enterprises and entrepreneurship, short supply chains and building skills.[27] Also from the United Kingdom, the Behaviour Insights team presented a range of strategies which target four key stakeholder groups (sustainability leaders, consumers/citizens, the food industry and governments), and reflect three critical pillars of dietary change; making sustainable food more appealing, normal and easy.[99]

In considering which strategies are most feasible to achieve a widespread shift to sustainable diets, we must first understand the drivers for change. One such driver is the habitual behaviour embedded in individuals over time and the cultural and social norms that support these habits.[97] Eker et al. used an integrated assessment model to demonstrate this social norm effect, whereby, for

example, high vegetarianism amongst a population will accelerate a further shift to a vegetarian diet amongst others in this same population group.[100] This example supports the need for investment in strategies that are motivated by either intrinsic identity or by group dynamics, to effectively achieve this population-level shift towards healthy and sustainable diets.[100] Importantly, the food system must support these social changes throughout the food supply chain, beyond just the consumption phase. For example, if strategies to trigger this social norm effect are successful in promoting a reduced intake of meat, the system must offer adequate sustainably grown and processed plant-based protein options. With many strategy options being discussed, it is vital to also consider available mechanisms to ensure best-practice evidence is translated into policy decision-making. An example of such a mechanism, the Food Systems Dashboard, was created in 2020 to visually present curated data from public and private sources to identify context-specific levers for change to inform policy decision-making at a country level.[101] Lawrence et al. developed a policy formulation tool to strategically inform food and nutrition policy that aims to promote healthy and sustainable diets.[102] They present an 'Orders of Food Systems Change' schema, intended to guide policymaking through (i) first order change related to *adjusting* individual components of the food system to improve their performance efficiency, (ii) second order change related to *reforming* interaction between and within the inter-related components of the food system and (iii) third order change which focuses on *transforming* the orientation of the food system as a whole, so that it becomes a tool to facilitate healthy and sustainable diets.[102]

In reviewing current evidence about the efficacy of various policy options to facilitate the uptake of healthy and sustainable diets, the policies presented in Table 5 were identified. In addition to these policy options, dietary guidelines are an effective mechanism to promote healthy and sustainable diets.[92,146] Dietary guidelines are implemented at a Federal Government level and serve as an evidence-informed reference standard to guide policy activities and inform research into population diets.[146]

Springmann et al. identified from their modelling of 85 countries that the adoption of food-based dietary guidelines improved health outcomes and reduced greenhouse gas emissions.[92] Their analysis however suggested that national guidelines could be healthier and more sustainable, in particular limiting the consumption of animal-derived foods, increasing plant-based foods and wholegrains and attaining a balanced energy intake.[92] Reinhardt et al. conducted a systematic review of the evidence on dietary patterns and sustainability in the United States of America (USA), by comparing the sustainability of diets adhering to the dietary guidelines with current diets.[147] Their results challenged prior findings that diets adhering to the dietary guidelines were more sustainable than average diets, indicating that the USA dietary guidelines may lead to similar or increased greenhouse gas emissions, energy use, and water use compared to the current diet in the USA.[147] Ritchie et al. assessed the implications of a number of dietary guidelines including Australia's on greenhouse gas emissions and identified them to be highly inconsistent with the Paris Agreements' 1.5°C global warming target.[148] In comparing the average Australian intake to Australia's dietary guidelines, Hendrie et al. concluded that to promote health and environmental sustainability, dietary guidelines must facilitate a reduction in non-core foods and the consumption of no more than recommended serves of core food items, especially red meat.[15] With processed and ultra-processed food intake increasing globally, the NOVA categorisation framework is a recommended tool to inform the development of both healthier and more environmentally sustainable guidelines.[52,72,80] In assessing if and how environmental sustainability messages are included in food-based dietary guidelines, Fischer and Garnett identified firstly that only 83 of a possible 215 countries had official guidelines.[146] And of those with guidelines, only four countries at the time of this review had included sustainability messages; Brazil, Sweden, Qatar and Germany; and two countries, United States of America and Australia, had attempted to include them however failed to achieve government endorsement.[146]

As dietary guidelines are periodically reviewed by federal governments globally, it is essential that evidence on both health and sustainability is considered, and that this evidence considers biases involved in industry-funded studies. In looking to best-practice examples of dietary guidelines with prominent sustainability messages, scholars have published the evidence used to support Brazil's National Dietary Guidelines[149] and the development of Netherlands' healthy and sustainable food-based dietary guidelines.[150] Dietary guidelines are not only a tool to provide advice to the general public on foods, food groups and dietary patterns, they also form the basis for food policy decision-making and are therefore fundamental to shift consumption patterns in healthier and more environmentally sustainable directions.[150] As outlined in Table 5, there are a number of settings and policy options to facilitate the population-wide uptake of dietary guidelines.

4 | RECOMMENDATIONS

This position paper presents an overview of the current evidence to define and measure healthy and sustainable

TABLE 5 Settings and policy options which facilitate population-wide uptake of healthy and sustainable diets

Setting	Policy	Examples in the literature (countries where the example is drawn from)
Federal government	National food and nutrition strategy	• National Food Strategy (United Kingdom)[103,104] • Australia's attempt to create a National Food Plan (Australia)[105]
	Taxation	• Tax on sugar sweetened beverages and ultra-processed foods (Australia)[106]
Local government	Governance	• Engagement from Indigenous leaders in policy development (International)[24] • Policy and planning to influence local food environments (Australia)[107] • Food policy coalitions as a means to influence local food environments (Australia)[108] • Case study of Europe's 'Common Food Policy' to demonstrate how governance reforms can trigger a shift to healthy diets and sustainable food systems (Europe)[109] • City-region food system framework (International)[110] • Madrid – Role of cities in food governance (Spain)[111] • Co-developing (local government and key stakeholders) an indicators toolbox for action to support urban cities to evaluate performance according to food system sustainability (United Kingdom)[112]
	Modifying the local food environment	• Local government-led strategies as part of the Milan Urban Food Policy Pact (International)[113,114] • Food system sustainability from local to global approach (International)[115] • Participatory food policy-making process – Australian case study (Australia)[116] • Shaping physical, economic and policy components of food environments for healthy and sustainable diets (International)[44] • Benchmarking as a public health strategy to create healthy food environments – evaluation of INFORMAS (International)[117] • Improving food environments using INFORMAS (New Zealand)[118] • Multi-sector participatory approach working with community stores to enhance food security in remote Indigenous communities (Australia)[119] • Including alternative food networks (e.g. non-supermarket retail options and civil society groups) in urban policy (Italy)[120]
Food industry	Re-orientation of the retail food environment	• Restricting the merchandising of discretionary food and beverages in retail settings (Australia)[121] • Barriers and facilitators for creating healthy food retail outlets – perspectives from Australian local government authorities (Australia)[122] • Applying the ecological determinants of health perspective to reconsider the current retail foodscape (United States of America and Canada)[123] • A systematic review of factors influencing sustainable food consumption behaviours amongst university students, examining the effects of choice architecture interventions (International)[124]

(Continues)

TABLE 5 (Continued)

Setting	Policy	Examples in the literature (countries where the example is drawn from)
	Food labelling	• A systematic review comparing consumer preference for nutrition, environmental and social responsibility food labelling (International)[125] • A systematic review of sustainable food profiling models used to inform the development of food labels accounting for both nutrition and the environment (International)[94] • A systematic review and meta-analysis exploring the willingness to pay more for foods with environmental sustainability labels (International)[126] • Consideration of the practicalities of labelling to encourage sustainable food choices by consumers and trigger systemic changes (International)[127–130] • Traffic light labelling of meal choices as a method of persuasion (United Kingdom)[131]
Institutional	Institutional food service guidelines and auditing	• A systematic review of hospital food service; environmental and associated economic impacts, outcomes of strategies aiming to improve sustainability and perspectives of patients, staff and stakeholders about these strategies (International)[132] • A systematic review exploring consumer expectations and responses towards environmentally sustainable initiatives of foodservice operations (International)[133] • A systematic review of food waste audit methods in hospital food services – development of a consensus audit tool (International)[134] • Developing and implementing national-level healthy and sustainable guidelines in America for institutional food service settings (United States of America)[135,136] • Victoria's guidelines for healthy and high-quality food in public hospitals and aged care facilities (Australia)[137]
	Food procurement	• New York's public food procurement policies (United States of America)[138] • Copenhagen organic conversion in public kitchens (Denmark)[139] • Public food procurement as a policy instrument to address social, economic, environmental, health and nutrition outcomes by promoting sustainable food systems and diets (Brazil, Paraguay and United States of America)[140]
	Menu adaptation	• Meatless Monday in Armed Forces (Norway)[141] • Evaluation of meatless Monday in a National school meal program (United States of America)[142] • Impact of offering more vegetarian cafeteria meal options (United Kingdom)[143] • Improved school meals (health and environmental sustainability) using linear optimization, without negative effects on food waste, consumption or cost (Sweden)[144] • Randomised controlled field experiments nudging conference participants to select a vegetarian default lunch option (Denmark)[145]

TABLE 6 Policy options to promote healthy and sustainable diets

Domain	Policy area[47] (NOURISHING framework)	Policy recommendation	Policy leadership
Food environment	*N*utrition label standards and regulations on the use of claims and implied claims on food	• Integration of ecological principles in federally implemented, mandatory interpretive front-of-pack food labelling schemes • Warning labels on menus and displays in out of home venues (e.g. Carbon Footprint metrics, Ultra-Processed Food Advisory Statement)	Federal government Retail/hospitality setting
	*O*ffer healthy food and set standards in public institutions and other specific settings	• Procurement policies for public and private food service facilities (e.g. health services, prisons, aged-care, childcare, supported residential services) • Adequately resourced measures to reduce and reuse commercial and domestic food-related waste in line with circular economy principles (e.g. domestic and hospitality composting options) • Mandatory standards for food available in schools and other learning institutions (canteens and vending machines) and in their immediate vicinity	State government (to be implemented by local government) Department of Health Department of Education School communities
	*U*se economic tools to address food affordability and purchase incentives	• Tax on sugar sweetened beverages and nutrient-poor ultra-processed foods • Tax on foods produced using production practices which deplete natural resources, to incentivise demand for foods produced using regenerative production practices • Targeted subsidies/discounts on locally produced foods	Federal government Independent retailers
	*R*estrict food advertising and other forms of commercial promotion	• Restricted marketing of discretionary and ultra-processed foods to children (e.g. television, sports club sponsorships, posters on public transport, written and online communication) • Restricted marketing strategies (price, placement, product, promotion) of discretionary and ultra-processed foods in retail settings	Federal government
	*I*mprove nutritional quality of the whole food supply	• Reformulation of food products to prioritise less processed options (e.g. using the NOVA Framework to incentivise food manufacturers to focus on groups one, two and three and minimise the production of group four, the ultra-processed foods)	Food industry

(Continues)

TABLE 6 (Continued)

Domain	Policy area[47] (NOURISHING framework)	Policy recommendation	Policy leadership
	*S*et incentives and rules to create a healthy retail and food service environment	• Ensuring urban planning legislation/ requirements allow for equitable access to healthy and sustainable food (e.g. zoning regulations to prioritise farmers markets, green grocers, social solidarity supermarkets, bulk food stores over retail outlets selling fast food and ultra-processed foods) • Incentivise commercial kitchens (e.g. cafes and restaurants) to offer healthy and sustainable menu options by rewarding and promoting their efforts	Local government
Food system	*H*arness supply chain and actions across sectors to ensure coherence with health	• Invest in governance structures to engage multi-sectorial stakeholders including the community from across the food supply chain in healthy public policy (e.g. regional food networks, food policy coalitions, collective impact approaches) • Use public procurement policies to increase accessibility to fair trade, organic, locally produced (where planetary boundaries are respected) foods, ethically sourced Indigenous foods and food produced through regenerative agricultural practices • Work across all institutional settings to change food service provision (e.g. less animal-derived foods and more plant-based proteins on the menu, efforts to minimise food-related waste) to support social normative shifts • Support urban agriculture in health and planning policies • Implement sustainable soil management practices including measurement of carbon stocks to support growth of plant foods with optimal nutritional value reduce atmospheric carbon.	Local, state and federal governments Food industry Key stakeholders from throughout the food supply chain Federal government
Behaviour change communication	*I*nform people about food and nutrition through public awareness	• Integrate sustainability principles within future iterations of Australia's National dietary guidelines • Reorient the dietetics workforce to be equipped with skills and knowledge to influence action across the food system and contribute to these recommendations • Regular review of role statements to inspire and support nutritionists and dietitians to contribute to food system transformation • Public awareness campaigns and social marketing interventions to promote healthy and sustainable diet-related practices	Federal government International Dietitians Australia State governments

TABLE 6 (Continued)

Domain	Policy area[47] (NOURISHING framework)	Policy recommendation	Policy leadership
	*N*utrition advice and counselling in healthcare settings	• Training resources to enable the existing nutrition and dietetics workforce to implement healthy and sustainable food policy across various settings and areas of practice (e.g. British Dietetic Association's One Blue Dot program, training on healthy and sustainable food procurement and food service practices) • Professional development opportunities to equip nutritionists and dietitians to provide sound nutrition advice and counselling which considers the ecological outcomes of dietary advice • Development of education material and consumer resources for the general public on healthy and sustainable diets • Mandatory tertiary education on food sustainability for the future nutrition and dietetics workforce education[32,151] (e.g. competency standards, stand-alone units/modules relevant to the various areas of dietetic practice, integration of sustainability evidence and principles across the entire curricula)	Dietitians Australia Accreditation bodies Tertiary institutions
	*G*ive nutrition education and skills	• Professionals involved in delivering nutrition education and skills must consider the environmental impact of dietary behaviours, across the diverse practice areas (e.g. hospitals, health services, aged care, food industry, primary production, schools, early learning centres, recreation and community centres) • Training for stakeholders from the hospitality, food procurement and food service industries (e.g. caterers and food service providers) in incorporating sustainability principles into food procurement, food service practices and menus • Dietitians and Nutritionists working within the food industry can influence practices throughout the supply chain (e.g. procurement, manufacturing, distribution, packaging to increase public accessibility to healthy and sustainable diets	Healthcare professionals Hospitality, food procurement and food service Industries Food industry Food supply stakeholders

diets, and an overview of policy options to facilitate the uptake of healthy and sustainable diets. The NOURISHING Framework is intended to organise comprehensive policy options across three domains – food environment, food system and behaviour change – to promote healthier eating.[47] Table 6 presents an overview of existing policy options to facilitate the uptake of healthy and sustainable diets, as presented in the current literature, organised according to the NOURISHING Framework.[47]

Dietitians have an important role to play in contributing to global sustainable development targets, specific to and beyond efforts to transform our current food system.[20,21] This contribution relies on inter-sectoral collaboration, particularly with those required to undertake the most significant changes such as our food industry and the agricultural sector. The perspectives and expertise of Indigenous peoples is critical to effective governance and policy-making related to healthy and sustainable food systems. Based on Dietitians Australia's expertise, capacity to influence action and positioning within this policy area, the following four recommendations have been prioritised.

1. The development of a comprehensive, adequately resourced National Food and Nutrition Strategy which honours Indigenous knowledges on food systems, detailing a strategic plan to improve health, equity and sustainability outcomes of our food system (including policy options as presented in Table 6).
2. The prominent integration of ecological sustainability principles in the next iteration of Australia's dietary guidelines, to foster a population-wide demand for healthy and sustainable food to trigger and support change across the whole food system.
3. The reorientation of our food environment to prioritise access to healthy and sustainable dietary food options, including (i) a food labelling scheme which integrates health and ecological outcomes, (ii) settings-based approaches (e.g. food procurement policies for food services, retail and public facilities) and (iii) supportive federal and state policy to facilitate local government action.
4. Investment in capacity building activities for our current and future nutrition and dietetics workforce, including more opportunities for Aboriginal and Torres Strait Islander peoples to contribute to food system transformation through collective partnerships, effective tertiary education and continuing professional development.

It is critical that the opportunity is prioritised for Aboriginal and Torres Strait Islander People to be involved in the further development and translation of these recommendations into practice and policy.

5 | FUTURE RESEARCH OPPORTUNITIES

This position paper presents an overview of the current literature relevant to each of the three defined research questions, to inform the development of policy recommendations for Dietitians Australia and its members. The methods used to develop this position paper were designed within the scope of this project and have identified that future iterations of this position paper should be founded on traditional systematic or scoping review methodology.

This position paper identified some specific opportunities for future research. For example, as described by Lang, current evidence on sustainable diets suggests a need to shift the focus away from simply producing more food – the productionist mid-20th century policy vision - towards changing the *what* and *how* food is produced and consumed.[152] Ridoutt and Huang advise that research must prioritise efforts to demonstrate the environmental impact of ultra-processed and non-core foods.[76,153] This evidence has largely been overlooked in current reviews which have focussed on meat, dairy and agricultural practices.[153]

In terms of dietetic involvement in this research, a Delphi study identified that *food systems*, *health and nutrition promotion with the inclusion of planetary health and sustainability perspectives* should be considered a research priority for our profession over the coming decade.[154] In developing this position paper, it is clear that dietitians can continue to contribute to research which will inform evidence-based policy action, as recommended in this position paper. For example, dietitians can add to current research to identify opportunities and challenges to influence food environments in the settings in which they work, including reforms to food procurement, food service and food retail settings policies and practices, and influencing the food supply from within the food sector. Another example, is to consider how healthy and sustainable diets can be promoted through effective food governance and collaboration on key policy interventions such as Australia's National Preventative Health Strategy and the National Obesity Strategy.[155]

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CONFLICT OF INTEREST

Liza Barbour, Ellyn Bicknell, Stefanie Carino, Molly Fairweather, and Julie Brimblecombe are members of

Dietitians Australia. Elizabeth World is a staff member of Dietitians Australia. Mark Lawrence is a representative of Dietitians Australia's Advocacy and Policy Advisory Committee (APAC). The first author received funding from Dietitians Australia to lead the development of this paper.

AUTHOR CONTRIBUTIONS

All authors contributed to the design and approach taken to develop this position paper. LB drafted the manuscript and all authors contributed to revisions. All authors approved the final manuscript before submission. The content has not been published elsewhere. The authors acknowledge Dietitians Australia's Food and Environment Interest Group members for their advocacy efforts for the development of this position paper, and their input to the final manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

1. Food and Agriculture Organization, Alliance of Biodiversity International & International Centre for Tropical Agriculture (CIAT) Indigenous Peoples' food systems: Insights on sustainability and resilience from the front line of climate change. Rome; 2021.
2. Willett W, Rockström J, Loken B, et al. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet*. 2019;393:447-492.
3. Whitmee S, Haines A, Beyrer C, et al. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation & Commission on Planetary Health. *Lancet*. 2015; 386:1973-2028.
4. Mayes C. Unsettling food politics: agriculture, dispossession and sovereignty in Australia; 2018.
5. Tapsell LC, Probst Y, Lawrence M, et al. Food and nutrition security in the Australia-New Zealand region: impact of climate change. *World Rev Nutr Diet*. 2011;102:192-200.
6. Intergovernmental Panel on Climate Change. *Climate Change 2021: The Physical Science Basis*. Cambridge University Press; 2021.
7. The Lancet Planetary Health. The bigger picture of planetary health. *The Lancet Planetary Health*. 2019;3:e1.
8. Rockström J, Edenhofer O, Gaertner J, DeClerck F. Planet-proofing the global food system. *Nature Food*. 2020;1:3-5.
9. Afshin A, Sur PJ, Fay KA, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2019;393:1958-1972.
10. Swinburn BA, Kraak VI, Allender S, et al. The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report. *Lancet*. 2019;393:791-846.
11. World Health Organization AUSTRALIA: Noncommunicable Diseases (NCD) Country Profile. 2018. Accessed July 14, 2021. https://www.who.int/nmh/countries/aus_en.pdf
12. WA Department of Primary Industries and Regional Development. Agriculture and Food: how Australia accounts for agricultural greenhouse gas emissions, 2018.
13. EAT Foundation. Diets for a Better Future: Rebooting and Reimagining Healthy and Sustainable Food Systems in the G20. In: EAT-Lancet Commission on Food P, Health, editor, 2020
14. Hadjikakou M. Trimming the excess: environmental impacts of discretionary food consumption in Australia. *Ecol Econ*. 2017;131:119-128.
15. Hendrie G, Ridoutt B, Wiedmann T. Greenhouse gas emissions and the Australian diet—comparing dietary recommendations with average intakes. *Nutrients*. 2014;6:289-303.
16. Ridoutt B, Anastasiou K, Baird D, Garcia JN, Hendrie G. Cropland footprints of Australian dietary choices. *Nutrients*. 2020;12:1212.
17. Australian Bureau of Statistics. Scanner data to estimate household consumption: Experimental Food Estimates for Household Final Consumption Expenditure. 2018–2019. Accessed October 8, 2021. https://www.abs.gov.au/statistics/research/using-scanner-data-estimate-household-consumption-september-2021.
18. FAO, IFAD, UNICEF, WFP, WHO. The State of Food Security and Nutrition in the World 2021. Transforming Food Systems for Food Security, Improved Nutrition and Affordable Healthy Diets for all. Rome, Italy; 2021; 240.
19. Fanzo J, Davis C. Can Diets Be Healthy, Sustainable, and Equitable? *Current Obesity Reports*. 2019.
20. United Nations. Paris Agreement. *CN632016TREATIES-XXVII7d of 16 February 2016*, 2015.
21. United Nations General Assembly Transforming Our World: The 2030 Agenda for sustainable development. New York 2015.
22. United Nations. Food Systems Summit. 2021. Accessed July 14, 2021. https://www.un.org/en/food-systems-summit.
23. United Nations. United Nations Decade of Action on Nutrition (2016–2025). General Assembly on 1 April 2016.
24. Food and Agriculture Organization The White/Wiphala Paper on Indigenous Peoples' food systems. In: United Nations, editor. Rome, Italy, 2021.
25. Bhunnoo R. The need for a food-systems approach to policy making. *Lancet*. 2019;393:1097-1098.
26. High Level Panel of Experts. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome, 2017.
27. Parsons K, Hawkes C, Wells R. *What Is the Food System? A Food Policy Perspective. Brief 2*. Centre for Food Policy; 2019.
28. Hawkes C, Halliday J. What makes urban food policy happen? Insights from five case studies: International Panel of Experts on Sustainable Food Systems, 2017.
29. Dietitians Australia. Definition of a Dietitian. 2015. Accessed July 17, 2021. https://dietitiansaustralia.org.au/what-dietitans-do/definition-of-a-dietitian/.
30. Carlsson L, Seed B, Yeudall F. *The Role of Dietitians in Sustainable Food Systems and Sustainable Diets*. Dietitians of Canada; 2020.
31. Dietitians Australia. Food Systems and Environmental Sustainability Role Statement. 2019. Accessed July 14, 2021.

https://dietitiansaustralia.org.au/what-dietitans-do/information-for-healthcare-professionals/role-statements/.
32. Spiker ML, Knoblock-Hahn A, Brown K, et al. Cultivating sustainable, resilient, and healthy food and water systems: a nutrition-focused framework for action. *J Acad Nutr Diet*. 2020;120:1057-1067.
33. Landa AH, Szabo I, Le Brun L, Owen I, Fletcher G, Hill M. An evidence-based approach to scoping reviews. *Electron J Inform Syst Eval*. 2011;14:46-52.
34. Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med*. 2018;169:467-473.
35. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Social Res Methodol*. 2005;8:19-32.
36. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implement Sci*. 2010;5:69.
37. Colquhoun HL, Levac D, O'Brien KK, *et al*. Scoping Reviews: Time for Clarity in Definition, Methods, and Reporting. 2014.
38. Bonato S. Searching the Grey literature: a handbook for searching reports, working papers, and other unpublished research. *J Med Libr Assoc*. 2019;107:276-276.
39. Carlsson L, Callaghan E, Broman G. How can dietitians leverage change for sustainable food systems in Canada? *Can J Diet Pract Res*. 2019;80(4):164-171.
40. Position of the American Dietetic Association. Food and nutrition professionals can implement practices to conserve natural resources and support ecological sustainability. *J Am Diet Assoc*. 2007;107:1033-1043.
41. Burlingame B, Dernini S. Sustainable Diets and Biodiversity: Directions and Solutions for Policy, Research and Action. Proceedings of the International Scientific Symposium. FAO Headquarters, Rome, 2012.
42. Hawkes C, Jewell J, Allen K. A food policy package for healthy diets and the prevention of obesity and diet-related non-communicable diseases: the NOURISHING framework. *Obes Rev*. 2013;14:159-168.
43. Gussow JD, Clancy K. Dietary guidelines for sustainability. *J Nutr Educ*. 1986;18:1-5.
44. Drewnowski A, Monterrosa EC, de Pee S, Frongillo EA, Vandevijvere S. Shaping physical, economic, and policy components of the food environment to create sustainable healthy diets. *Food Nutr Bull*. 2020;41:74S-86S.
45. Lawrence M, Friel S. *Healthy and Sustainable Food Systems*. Routledge; 2020.
46. Ridoutt B, Hendrie G, Noakes M. Recommended diets in Australia are nutrient rich and have lower greenhouse gas emissions. *Public Health Nutr*. 2016;19:3245-3245.
47. Macdiarmid JI. Is a healthy diet an environmentally sustainable diet? *Proc Nutr Soc*. 2013;72:13-20.
48. Friel S, Barosh LJ, Lawrence M. Towards healthy and sustainable food consumption: an Australian case study. *Public Health Nutr*. 2014;17:1156-1166.
49. Johnston JL, Fanzo JC, Cogill B. Understanding sustainable diets: a descriptive analysis of the determinants and processes that influence diets and their impact on health, food security, and environmental sustainability. *Adv Nutr*. 2014;5:418-429.
50. Nelson ME, Hamm MW, Hu FB, Abrams SA, Griffin TS. Alignment of healthy dietary patterns and environmental sustainability: a systematic review. *Adv Nutr*. 2016;7:1005-1025.
51. von Koerber K, Bader N, Leitzmann C. Wholesome nutrition: an example for a sustainable diet. *Proc Nutr Soc*. 2017;76:34-41.
52. Monteiro CA, Cannon G, Moubarac JC, Levy RB, Louzada MLC, Jaime PC. The UN decade of nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutr*. 2018;21:5-17.
53. World Health Organization A healthy diet sustainably produced - information sheet. 2018.
54. Smetana SM, Bornkessel S, Heinz V. A path from sustainable nutrition to nutritional sustainability of complex food systems. *Front Nutr*. 2019;6:39.
55. Lawrence MA, Baker PI, Pulker CE, Pollard CM. Sustainable, resilient food systems for healthy diets: the transformation agenda. *Public Health Nutr*. 2019;22(16):2916-2920.
56. Food and Agriculture Organization, World Health Organization Sustainable healthy diets - guiding principles. Rome, 2019.
57. Kuhnlein HV, Eme, P, Fernández-de-Larrinoa, Y. Indigenous food systems: contributions to sustainable food systems and sustainable diets. 2019.
58. Barbour L, Woods J, Brimblecombe J. Translating evidence into policy action: which diet-related practices are essential to acheive healthy and environmentally sustainable food system transformation? *Aust N Z J Public Health*. 2020;45:83-84.
59. Milbank C, Burlingame B, Hunter D, et al. Rethinking hierarchies of evidence for sustainable food systems. *Nature Food*. 2021;2:843-845.
60. Kumanyika S, Afshin A, Arimond M, Lawrence M, McNaughton SA, Nishida C. Approaches to defining healthy diets: a background paper for the international expert consultation on sustainable healthy diets. *Food Nutr Bull*. 2020;41:7S-30S.
61. Monteiro CA, Cannon G, Levy RB, et al. Ultra-processed foods: what they are and how to identify them. *Public Health Nutr*. 2019;22:936-941.
62. Costa CS, Del-Ponte B, Assunção MCF, Santos IS. Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review
63. Chen X, Zhang Z, Yang H, et al. Consumption of ultra-processed foods and health outcomes: a systematic review of epidemiological studies
64. Pagliai G, Dinu MA-O, Madarena MP, Bonaccio M, Iacoviello L, Sofi F. Consumption of ultra-processed foods and health status: a systematic review and meta-analysis
65. Silva Meneguelli TA-O, Viana Hinkelmann J, Hermsdorff HA-O, Zulet MÁ A-O, Martínez JA-O, Bressan JA-O. Food consumption by degree of processing and cardiometabolic risk: a systematic review
66. Santos FSD, Dias MDS, Mintem GC, Oliveira IO, Gigante DP. Food processing and cardiometabolic risk factors: a systematic review
67. Lane MM, Davis JA, Beattie S, et al. Ultraprocessed food and chronic noncommunicable diseases: a systematic review and meta-analysis of 43 observational studies. *Obes Rev*. 2021;22:e13146.
68. Askari MA-O, Heshmati J, Shahinfar HA-O, Tripathi NA-O, Daneshzad EA-O. Ultra-processed food and the risk of overweight and obesity: a systematic review and meta-analysis of observational studies

69. Moradi S, Entezari MH, Mohammadi H, et al. Ultra-processed food consumption and adult obesity risk: a systematic review and dose-response meta-analysis
70. Elizabeth L, Machado P, Zinöcker M, Baker P, Lawrence M. Ultra-processed foods and health outcomes: a narrative review. *Nutrients*. 2020;12:1995.
71. Machado PP, Steele EM, Levy RB, et al. Ultra-processed foods and recommended intake levels of nutrients linked to non-communicable diseases in Australia: evidence from a nationally representative cross-sectional study. *BMJ Open*. 2019;9:e029544.
72. Fardet A, Rock E. Ultra-processed foods and food system sustainability: what are the links? *Sustainability*. 2020;12:6280.
73. Ridoutt BG, Hendrie GA, Noakes M. Dietary strategies to reduce environmental impact: a critical review of the evidence base. *Adv Nutr*. 2017;8:933-946.
74. Chai BC, van der Voort JR, Grofelnik K, Eliasdottir HG, Klöss I, Perez-Cueto FJA. Which diet has the least environmental impact on our planet? A systematic review of vegan, vegetarian and omnivorous diets. *Sustainability*. 2019;11:4110.
75. Mehlig K, Blomqvist I, Klingberg S, et al. Secular trends in diet-related greenhouse gas emission estimates since 2000 – a shift towards sustainable diets in Sweden. *Public Health Nutr*. 2021;24:3916-3921.
76. Ridoutt BG, Baird D, Hendrie GA. Diets within planetary boundaries: what is the potential of dietary change alone? *Sustain Prod Consum*. 2021;28:802-810.
77. Forbes SA-O, Bicknell E, Guilovica L, Wingrove KA-O, Charlton KA-OX. A rapid review of the environmental impacts associated with food consumption in Australia and New Zealand. *Curr Nutr Rep*. 2021;10:334-351.
78. Shamsi S, Williams M, Mansourian Y. An introduction to aboriginal fishing cultures and legacies in seafood sustainability. *Sustainability*. 2020;12(22):1–17.
79. Hachem F, Vanham D, Moreno LA. Territorial and sustainable healthy diets. *Food Nutr Bull*. 2020;41:87S-103S.
80. Baker P, Machado P, Santos T, et al. Ultra-processed foods and the nutrition transition: global, regional and national trends, food systems transformations and political economy drivers. *Obes Rev*. 2020;21:e13126.
81. Burns K, Hubay S, King B, Vanderkooy P, Wilkie J. *Nutritious Food Basket: Guidance Document*. Ontaria, Canada; 2010.
82. Queensland Health. *The Healthy Food Access Basket Survey 2000*. Queensland; 2000.
83. Lewis M, Lee A. Costing 'healthy' food baskets in Australia – a systematic review of food price and affordability monitoring tools, protocols and methods. *Public Health Nutr*. 2016;19:2872-2886.
84. Barosh L, Friel S, Engelhardt K, Chan L. The cost of a healthy and sustainable diet – who can afford it? *Aust N Z J Public Health*. 2014;38:7-12.
85. Goulding T, Lindberg R, Russell CG. The affordability of a healthy and sustainable diet: an Australian case study. *Nutr J*. 2020;19:109.
86. Donati M, Menozzi D, Zighetti C, Rosi A, Zinetti A, Scazzina F. Towards a sustainable diet combining economic, environmental and nutritional objectives. *Appetite*. 2016;106:48-57.
87. Mertens E, Kuijsten A, Kanellopoulos A, et al. Improving health and carbon footprints of European diets using a benchmarking approach. *Public Health Nutr*. 2021;24:565-575.
88. Chen C, Chaudhary A, Mathys A. Dietary change scenarios and implications for environmental, nutrition, human health and economic dimensions of food sustainability. *Nutrients*. 2019;11(4):856.
89. Wrieden W, Halligan J, Goffe L, Barton K, Leinonen I. Sustainable diets in the UK—developing a systematic framework to assess the environmental impact, cost and nutritional quality of household food purchases. *Sustainability*. 2019;11:4974.
90. Allen T, Prosperi P, Cogill B, Padilla M, Peri I. A Delphi approach to develop sustainable food system metrics. *Social Indic Res*. 2019;141:1307-1339.
91. Clark MA, Springmann M, Hill J, Tilman D. Multiple health and environmental impacts of foods. *Proceedings of the National Academy of Sciences of the United States of America*. 2019;116(46):23357–23362.
92. Springmann M, Spajic L, Clark MA, et al. The healthiness and sustainability of national and global food based dietary guidelines: modelling study. *BMJ*. 2020;370:m2322.
93. Jarmul S, Dangour AA-O, Green R, Liew Z, Haines A & Scheelbeek PA-O Climate change mitigation through dietary change: a systematic review of empirical and modelling studies on the environmental footprints and health effects of 'sustainable diets'. 2020
94. Bunge AC, Wickramasinghe K, Renzella J et al. Sustainable food profiling models to inform the development of food labels that account for nutrition and the environment: a systematic review 2021
95. Candy S, Turner G, Larsen K, et al. Modelling the food availability and environmental impacts of a shift towards consumption of healthy dietary patterns in Australia. *Sustainability*. 2019;11:7124.
96. Madzorera I, Jaacks L, Paarlberg R, et al. Food systems as drivers of optimal nutrition and health: complexities and opportunities for research and implementation. *Curr Dev Nutr*. 2021;5(Supplement):1–8.
97. Béné C, Fanzo J, Haddad L, et al. Five priorities to operationalize the EAT–Lancet Commission report. *Nat Food*. 2020;1:457-459.
98. Parsons K, Hawkes C. Connecting food systems for co-benefits: How can food systems combine diet-related health with environmental and economic policy goals? World Health Organisation. Regional Office for Europe (Copenhagen, Denmark): European Observatory on Health Systems and Policies; 2018. Available: https://apps.who.int/iris/handle/10665/331979
99. Park T & Team TBI A menu for change: using behavioural science to promote sustainable diets around the world. In: , ed. Beahviour Insights Ltd.; 2020.
100. Eker S, Reese G, Obersteiner M. Modelling the drivers of a widespread shift to sustainable diets. *Nat Sustain*. 2019;2:725-735.
101. Fanzo J, Haddad L, McLaren R, et al. The food systems dashboard is a new tool to inform better food policy. *Nat Food*. 2020;1:243-246.
102. Lawrence MA, Friel S, Wingrove K, James SW, Candy S. Formulating policy activities to promote healthy and sustainable diets. *Public Health Nutr*. 2015;18:2333-2340.
103. Bhunnoo R, Poppy GM. A national approach for transformation of the UK food system. *Nat Food*. 2020;1:6-8.

104. Walton S, Hawkes C. *What we Can Learn: A Review of Food Policy Innovations in Six Countries*. London, United Kingdom; 2020.
105. Carey R, Caraher M, Lawrence M, Friel S. Opportunities and challenges in developing a whole-of-government national food and nutrition policy: lessons from Australia's National Food Plan. *Public Health Nutr*. 2016;19:3-14.
106. Sacks G, Kwon J, Backholer K. Do taxes on unhealthy foods and beverages influence food purchases? *Curr Nutr Rep*. 2021; 10(3):179–187.
107. Bivoltsis A, Trapp G, Knuiman M, Hooper P, Ambrosini GL. The influence of the local food environment on diet following residential relocation: longitudinal results from RESIDential Environments (RESIDE). *Public Health Nutr*. 2020;23:2132-2144.
108. McCartan J, Palermo C. The role of a food policy coalition in influencing a local food environment: an Australian case study. *Public Health Nutr*. 2017;20:917-926.
109. De Schutter O, Jacobs N, Clément C. A 'common food policy' for Europe: how governance reforms can spark a shift to healthy diets and sustainable food systems. *Food Policy*. 2020; 96:101849.
110. Blay-Palmer A, Santini G, Dubbeling M, Renting H, Taguchi M, Giordano T. Validating the City region food system approach: enacting inclusive, Transformational City Region Food Systems. *Sustainability*. 2018;10(5):1680.
111. Zerbian T, de Luis RE. The Role of Cities in Good Governance for Food Security: Lessons from Madrid's Urban Food Strategy. *Territ Politics Gov*. 2021;9:1-19.
112. Moragues-Faus A, Marceau A. Measuring progress in sustainable food cities: an indicators toolbox for action. *Sustainability*. 2019;11(1):45.
113. Candel JJL, Pereira L. Towards integrated food policy: main challenges and steps ahead. *Environ Sci Policy*. 2017;73:89-92.
114. Candel JJL. What's on the menu? A global assessment of MUFPP signatory cities' food strategies. *Agroecol Sustain Food Syst*. 2019;44(7):919-946.
115. Carlsson L, Callaghan E, Morley A, Broman G. Food system sustainability across scales: a proposed local-to-global approach to community planning and assessment. *Sustainability*. 2017;9(6):1061.
116. Lourival I, Rose N. From Nar Nar goon to Koo wee Rup: can participatory food policy making processes contribute to healthier and fairer food Systems in the Australian Municipal Context? A case study from Cardinia Shire, Melbourne. *J Hunger Environ Nutr*. 2020;15:1-35.
117. Sacks G, Kwon J, Vandevijvere S, Swinburn B. Benchmarking as a public health strategy for creating healthy food environments: an evaluation of the INFORMAS initiative (2012–2020). *Annu Rev Public Health*. 2021;42:345-362.
118. Vandevijvere S, Mackay S, D'Souza E, Swinburn B. The first INFORMAS national food environments and policies survey in New Zealand: a blueprint country profile for measuring progress on creating healthy food environments. *Obes Rev*. 2019;20:141-160.
119. Brimblecombe J, Bailie R, van den Boogaard C, et al. Feasibility of a novel participatory multi-sector continuous improvement approach to enhance food security in remote Indigenous Australian communities. *SSM - Populat Health*. 2017;3:566-576.
120. Matacena R. Linking alternative food networks and urban food policy: a step forward in the transition towards a sustainable and equitable food system? *Int Rev Social Res*. 2016;6:49-58.
121. Brimblecombe J, McMahon E, Ferguson M, et al. Effect of restricted retail merchandising of discretionary food and beverages on population diet: a pragmatic randomised controlled trial. *Lancet Planet Health*. 2020;4:e463-e473.
122. Boelsen-Robinson T, Peeters A, Thow A-M, Hawkes C. Barriers and facilitators to implementing a healthier food outlet initiative: perspectives from local governments. *Public Health Nutr*. 2021;24:2758-2770.
123. Elton S. Reconsidering the retail foodscape from a posthumanist and ecological determinants of health perspective: wading out of the food swamp. *Crit Public Health*. 2018;29:370-378.
124. Aguirre Sánchez L, Roa-Díaz ZM, Gamba M, et al. What influences the sustainable food consumption Behaviours of university students? A systematic review. *Int J Public Health*. 2021;66:1604149.
125. Tobi RCA, Harris F, Rana R, Brown KA, Quaife M, Green R. Sustainable diet dimensions. Comparing consumer preference for nutrition, environmental and social responsibility food labelling: a systematic review. *Sustainability*. 2019;11(23):6575.
126. Bastounis A, Buckell J, Hartmann-Boyce J, et al. The impact of environmental sustainability labels on willingness-to-pay for foods: a systematic review and meta-analysis of discrete choice experiments. *Nutrients*. 2021;13:2677.
127. Brown KA, Harris F, Potter C, Knai C. The future of environmental sustainability labelling on food products. *Lancet Planet Health*. 2020;4:e137-e138.
128. Potter C, Bastounis A, Hartmann-Boyce J, et al. The effects of environmental sustainability labels on selection, purchase, and consumption of food and drink products: a systematic review. *Environ Behav*. 2021. 53(8):891-925.
129. Leach AM, Emery KA, Gephart J, et al. Environmental impact food labels combining carbon, nitrogen, and water footprints. *Food Policy*. 2016;61:213-223.
130. Bastounis A, Buckell J, Hartmann-Boyce J, et al. The impact of environmental sustainability labels on willingness-to-pay for foods: a systematic review and meta-analysis of discrete choice experiments. *Nutrients*. 2021;13(8):2677.
131. Osman M, Thornton K. Traffic light labelling of meals to promote sustainable consumption and healthy eating. *Appetite*. 2019;138:60-71.
132. Carino S, Porter J, Malekpour S, Collins J. Environmental sustainability of hospital foodservices across the food supply chain: a systematic review. *J Acad Nutr Diet*. 2020;120:825-873.
133. Sullivan VS, Smeltzer ME, Cox GA-OX, MacKenzie-Shalders KA-O. Consumer expectation and responses to environmental sustainability initiatives and their impact in foodservice operations: a systematic review. *J Hum Nutr Diet*. 2021;34(6):1-20.
134. Cook N, Collins J, Goodwin D, Porter J. A systematic review of food waste audit methods in hospital foodservices: development of a consensus pathway food waste audit tool. *J Hum Nutr Diet*. 2021;1-13.
135. Kimmons J, Jones S, McPeak HH, Bowden B. Developing and implementing health and sustainability guidelines for institutional food service. *Adv Nutr*. 2012;3:337-342.
136. Food Service Guidelines Federal Working Group. *Food Service Guidelines for Federal Facilities*. Washington, DC, United States of America; 2017.

137. Victorian Government Healthy and high-quality food in public hospitals and aged care facilities. Department of Health. 2021. Accessed August 6. https://www2.health.vic.gov.au/hospitals-and-health-services/quality-safety-service/healthy-choices.
138. Libman K, Li A, Grace C. The public plate in New York states: growing health, farms and jobs with local food. In: Trust AF, Workgroup DaSaHND-N, (FINYS) FtINYS, Medicine NYAo, eds. New York, USA; 2017.
139. Food and Agriculture Organization. *Milan Urban Food Policy Pact Special Mention: Copenhagen - Organic Conversion in Public Kitchens*. United Nations; 2017.
140. Swensson LFJ, Tartanac F. Public food procurement for sustainable diets and food systems: the role of the regulatory framework. *Glob Food Sec*. 2020;25:100366.
141. Milford AB, Kildal C. Meat reduction by force: the case of "meatless Monday" in the Norwegian armed forces. *Sustainability*. 2019;11(10):2741.
142. Blondin SA, Cash SB, Griffin TS, Goldberg JP, Economos CD. Meatless Monday National School Meal Program Evaluation: impact on nutrition, cost, and sustainability. *J Hunger Environ Nutr*. 2020;15:1-13.
143. Garnett EE, Balmford A, Sandbrook C, Pilling MA, Marteau TM. Impact of increasing vegetarian availability on meal selection and sales in cafeterias. *Proc Natl Acad Sci*. 2019;116:20923.
144. Eustachio Colombo P, Patterson E, Lindroos AK, Parlesak A, Elinder LS. Sustainable and acceptable school meals through optimization analysis: an intervention study. *Nutr J*. 2020;19:61.
145. Hansen PG, Schilling M, Malthesen MS. Nudging healthy and sustainable food choices: three randomized controlled field experiments using a vegetarian lunch-default as a normative signal. *J Public Health*. 2021;43:392-397.
146. Fischer C, Garnett T. Plates, pyramids and planets. Developments in national healthy and sustainable dietary guidelines: a state of play assessment. FAO and the Food Climate Research Network at The University of Oxford, 2016.
147. Reinhardt SL, Boehm R & Blackstone NT et al. Systematic Review of Dietary Patterns and Sustainability in the United States; 2020
148. Ritchie H, Reay DS, Higgins P. The impact of global dietary guidelines on climate change. *Glob Environ Chang*. 2018;49:46-55.
149. Louzada M, Canella D, Jaime P, Monteiro C. Food and health: the scientific evidence informing the dietary guidelines for the Brazilian population. 2019.
150. Brink E, van Rossum C, Postma-Smeets A, et al. Development of healthy and sustainable food-based dietary guidelines for The Netherlands. *Public Health Nutr*. 2019;22:2419-2435.
151. Den Boer ACL, Broerse JEW, Regeer BJ. The need for capacity building to accelerate food system transformation. *Curr Opin Food Sci*. 2021;42:119-126.
152. Lang T. The sustainable diet question: reasserting societal dynamics into the debate about a good diet. *Int J Sociol Agric Food*. 2021;27:12-34.
153. Ridoutt B, Huang J. Three main ingredients for sustainable diet research. *Environ Sci Technol*. 2019;53:2948-2949.
154. Porter J, Charlton K, Tapsell L, Truby H. Using the Delphi process to identify priorities for dietetic research in Australia 2020-2030. *Nutr Diet*. 2020;77:437-443.
155. Commission for the Human Future. *The Need for Strategic Food Policy in Australia: Governing for a Healthy, Sustainable, Economically Viable and Resilient Food System*. Commission for the Human Future; 2020:10.

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REVIEW

The effects of the COVID-19 pandemic on food security in Australia: A scoping review

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Abstract

Aim: The COVID-19 pandemic has disrupted the Australian food supply with potential ramifications on food security. This scoping review aimed to synthesise current evidence on the prevalence of food insecurity and changes to factors related to food insecurity during the COVID-19 pandemic in Australia.

Methods: A comprehensive search strategy was used to search seven databases (MEDLINE, CINAHL, Embase, Global Health, Cochrane Database of Systematic Reviews, PsycINFO, Informit Online) and Google Scholar. Included studies were written in English, published in 2020–2021 and examined food security status in Australia during the COVID-19 pandemic and/or factors associated with food insecurity in free-living Australian residents. Articles with participants residing in institutional settings, where meals were supplied, were excluded.

Results: A total of 700 records were identified from database, grey literature and hand searching, and nine articles were included. All studies indicated that the prevalence of food insecurity had increased due to negative changes to food availability, accessibility, usability and stability. The downturn in employment and economic circumstances following the onset of the COVID-19 pandemic appeared to create a new group of food-insecure Australians consisting of newly unemployed, and international students.

Conclusion: COVID-19 has exacerbated vulnerabilities in the Australian food supply and food security. Suggested actions include ongoing data collection on the long-term impact of COVID-19 on food supply and security in addition to coordinated national and community responses that improve the stability of the local food supply and address underlying determinants of food insecurity.

KEYWORDS

Australia, COVID-19, food accessibility, food availability, food insecurity, food supply

1 | INTRODUCTION

The COVID-19 pandemic, alongside natural disasters such as bushfires, cyclones, storms and floods occurring in 2020, precipitated unprecedented social and economic disruptions potentially exacerbating the prevalence of food insecurity in Australia.[1–5] Food security is defined as consistent physical, social and economic access to sufficient and safe food that meets nutritional needs and food preferences.[6] In addition to accessibility, other pillars of food security include food availability, utilisation and the stability of these factors to withstand climatic, economic, social and/or political changes.[6,7] Subsequently, food insecurity occurs when one or more of these domains are not met temporarily or in the longer term.[7] The temporary disruption to food supply chains in 2020 may have led to compromises in nutrition, food preferences and forced acculturation due to decreased availability and accessibility to locally produced and imported food products.[3]

The response to COVID-19 by the Federal government involved closing international borders and introducing mandatory quarantine for returning Australian citizens.[8] Lockdown protocols, behavioural restrictions and border regulations varied between the States and Territories. Western Australia has been the least locked down state (12 days) but maintains closed borders when eastern states have experienced COVID-19 outbreaks, whereas Melbourne, Victoria, has been the 'world's most locked down city' (262 days).[9,10] In New South Wales, there was an initial lockdown, and targeted lockdown in Sydney Northern beaches in December 2020, then a 107-day lockdown in 2021 following the arrival of the Delta variant in Sydney.[11,12]

Employment and income have been significantly impacted by COVID-19 with underemployment reaching a historic high of 13.8% in Australia, the equivalent of 1.8 million people working reduced hours or becoming unemployed.[4] Between March and June 2020, a 5.7% reduction in the number of payroll jobs occurred.[13] In response, the Federal Government provided JobKeeper payments to help businesses pay their employees, and the Coronavirus Supplement for eligible recipients in addition to regular income support payments.[14,15] The Coronavirus Supplement rate of $550 per fortnight almost doubled the maximum JobSeeker payment rate until September 2020 when it was reduced to $250 per fortnight, and then again in January to $150 per fortnight.[16,17] The JobKeeper rate similarly decreased from $1500 fortnightly to $1000. By the end of March 2021, JobKeeper and the Coronavirus Supplement ceased,[16] but JobSeeker payments remain available for the unemployed albeit the loss of the Coronavirus Supplement made payments barely above the poverty line (defined as 50% of median household income).[18,19]

Collective changes in employment, income and food supply during COVID-19 are expected to have amplified the prevalence and extent of food insecurity and affected population groups that were not affected previously.[6] Food insecurity in Australia has historically been associated with food prices, and socioeconomic or cultural disadvantage.[20–22] Prior to COVID-19, the prevalence of food insecurity in Australia has been estimated to be 4% to 14% in the general population and up to 82% in vulnerable groups being similar across the country.[20–31] This represents at least one million Australians experiencing food insecurity pre-COVID-19.[23] It is also highly likely that the single-item question assessing food insecurity underestimates the level of food insecurity by more than 5%.[32,33]

Recent trends have predicted an increase in the prevalence of undernourishment in Australia and New Zealand from 5.8% in 2019 to 7.0% in 2030 (equivalent to 2.4–3.4 million) without accounting for the impact of the COVID-19 pandemic.[6] The predicted rise in the prevalence of food insecurity is particularly concerning for those vulnerable prior to the pandemic such as people living in rural and remote areas, Aboriginal and Torres Strait Islander people, people experiencing homelessness, single-parent households, people with a disability, the elderly, the immunocompromised and those relying on welfare payments.[21]

Food insecurity is associated with poor diet quality, obesity, reduced short and long-term health status, and higher mortality rates adding to individual suffering and the financial burden on healthcare services.[6,20,22,34–36]

Therefore, this scoping review aimed to examine and synthesise the emerging evidence base on the impact of COVID-19 on the prevalence of food insecurity in Australia and the factors related to changes in food insecurity that have occurred.

2 | METHODS

The scoping review was conducted according to the Joanna Briggs Institute methodology for scoping reviews[38] and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Extension for Scoping Reviews Checklist.[39] The review protocol has been published on the Open Science platform https://osf.io/zdp58/.

A preliminary search of medical databases and review registries yielded no current or underway scoping or systematic reviews on the concept of COVID-19 and food insecurity in Australia. As this was a new and emerging

topic, it was determined that a scoping review would be most appropriate to map the types and volume of available literature on the concept, determine current knowledge gaps, and provide an overview of evidence to inform future studies and/or systematic reviews.[37]

The following questions were used to guide this review: (i) What is the prevalence of food insecurity in Australia during the COVID-19 pandemic? (ii) What changes in food security have occurred in Australia during the COVID-19 pandemic? (iii) What factors have influenced these changes? The search strategy aimed to identify published and unpublished primary studies, reviews and reports according to the three-step strategy recommended by the Joanna Briggs Institute. An initial search was conducted to identify relevant articles in MEDLINE (PubMed) and CINAHL (EBSCO). Based on keywords and phrases identified in the initial search, a full search strategy was developed for MEDLINE (PubMed) with assistance from a research librarian. A full search in the selected databases was conducted on the 4th of April 2021 using all identified keywords and index terms. Key terms related to all aspects of food security were included for comprehensive results. The search strategy, keywords and index terms were adapted for each information source. Online supplementary file I contains the search strategies utilised in MEDLINE. Finally, reference lists of selected articles were screened for additional papers. The language of included publications was limited to English and the publication year was set to 2020 and onwards since the aim was to map evidence on the impact of COVID-19. The publication year limit was not applied when searching the Google Scholar database to prevent false exclusion since articles do not always have a publication year.

Electronic databases searched included MEDLINE (via Ovid), CINAHL (via EBSCO), Embase (via Ovid), Global Health (via Ovid), Cochrane Database of Systematic Reviews (via Ovid), PsycINFO (via Ovid) and Informit Online. Unpublished studies and grey literature were searched using Google Scholar.

This review included studies on free-living individuals residing in Australia from 2020 onwards. This included people who may not be Australian citizens such as those born in foreign countries who entered Australia for tertiary education or extended travel prior to the travel ban on the 20th of March 2020. There were no restrictions on age, sex, employment, socioeconomic status or education. Studies that examined food security status in Australia during COVID-19 were included. The concept of food security encompassed the four domains of food security (food accessibility, affordability, availability and stability) as well as acceptability, nutritional requirements, food preferences and access to culturally appropriate foods. Food preferences and culturally appropriate foods were included for their importance in attaining an inclusive and culturally relevant understanding of food security within the multicultural Australian context. Factors associated with food security such as education, food prices, household structure, income and food environment were also included. This review considered studies based on the Australian community at large and excluded institutionalised settings where food was provided such as aged care homes or hospitals, to focus on free-living individuals. All study designs (quantitative, qualitative and mixed method), systematic reviews and grey literature (excluding news articles and opinion pieces) were considered.

All citations from the full search were imported into EndNote X9.2 (Clarivate Analytics, PA, USA). After removing duplicates, two independent reviewers screened the titles and abstracts against the inclusion criteria. Full texts for potentially relevant papers were retrieved and screened by both reviewers. Reasons for excluding studies that did not meet the inclusion criteria were recorded. Any disagreements between two reviewers at each stage were resolved through discussion or consultation with a third reviewer.

A data charting form was developed for this review and used to extract data from included papers. Extracted data included citation, participant sample and characteristics, study aims, research design, data collection and analysis, primary outcomes (i.e. prevalence of food insecurity) and secondary outcomes (i.e. factors associated with food insecurity) and study limitations. The data extraction tool was used iteratively and modified throughout data extraction as needed. Both reviewers extracted data for all included studies independently then compared and discussed the data to resolve discrepancies.

Key demographics and findings for all included studies were summarised in tables. For qualitative findings, a thematic analysis was conducted. Themes from the review questions guided the approach with additional themes identified during analysis of the papers. Findings were presented in a tabular form. Representative quotations were selected by two reviewers and presented thematically. A descriptive summary of all studies was created to report the impact of COVID-19 on food security in Australia during the pandemic.

3 | RESULTS

The full search identified 689 articles from databases ($n = 360$) and grey literature ($n = 329$), and 11 articles

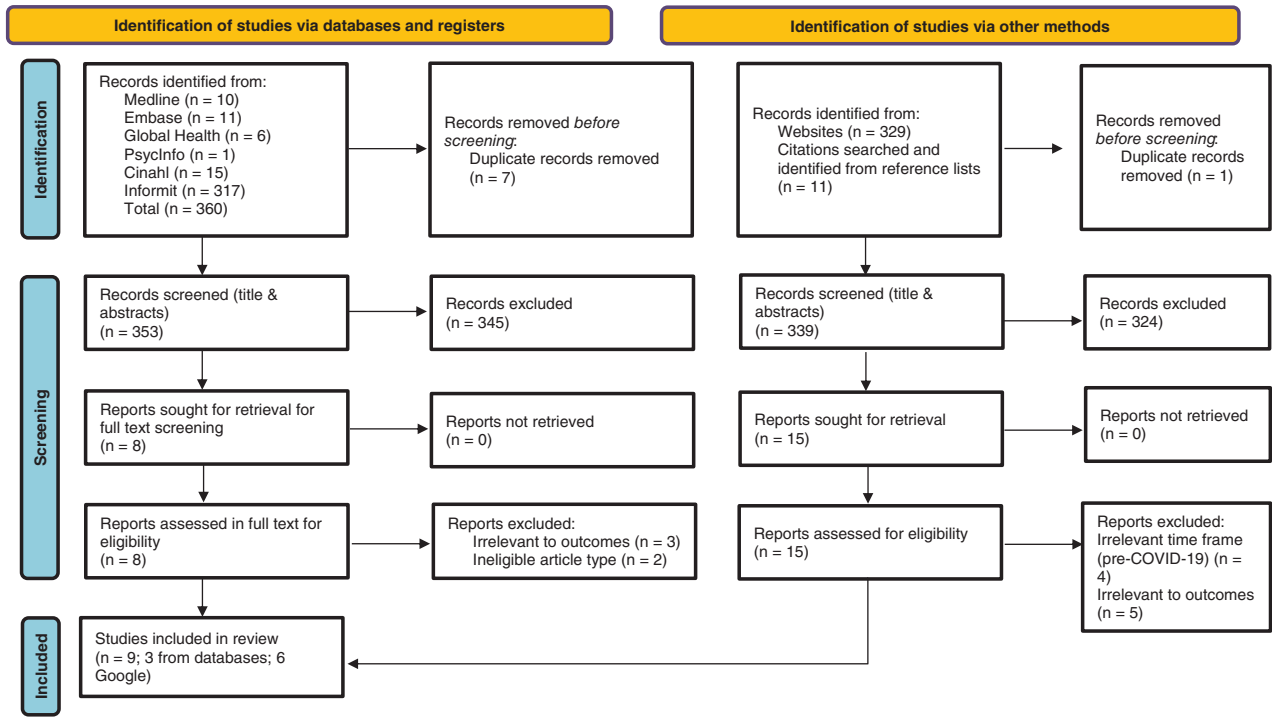

FIGURE 1 PRISMA flow diagram of record identification and study selection

from the reference lists of included studies (Figure 1). After removing duplicates, the titles and abstracts of the remaining 692 citations were screened, then the remaining 23 articles were screened in full text. Nine studies were included in the final synthesis. Reasons for exclusion after full-text screening are listed in the PRISMA flow diagram (Figure 1) and online supplementary file II.

Table 1 depicts the study (aim, study design, data collection methods) and demographic characteristics of participants such as sample size, age and gender. The majority of the included studies were from Victoria ($n = 3$)[40–42] followed by New South Wales ($n = 2$),[43,44] all states ($n = 2$),[45,46] Tasmania ($n = 1$)[47] and Western Australia ($n = 1$).[48] Study participants included food relief providers ($n = 4$),[40,41,43,45] Aboriginal community members ($n = 1$)[44] and the general Australian population ($n = 5$).[42,45–48] Sample sizes ranged from 4 to 1170 participants.

Of the included studies, there were three each of qualitative,[42–44] quantitative[40,41,47] and mixed-method study designs[45,46,48] (Table 1). Two studies employed a longitudinal design where data were collected at multiple time points.[45,48] Mixed-method studies combined cross-sectional or longitudinal surveys with a qualitative method.[45,46,48] All studies were conducted in 2020 and published between 2020 and 2021.

The most common quantitative data collection method was self-administered cross-sectional surveys with open and closed questions ($n = 5$).[40,41,45–47] The most common quantitative variables measured were the prevalence of COVID-related job changes and income loss,[40,45,47,48] prevalence of those receiving government welfare payments,[40,41,45,47,48] proportion of respondents reporting changes to food relief access[40,41,45,48] and sociodemographic characteristics of the food insecure.[40,41,45–47] Only two studies quantitatively measured the prevalence of food insecurity using the validated USDA six-Item Short Form Household Food Security Survey Module (HFSSM) or a single item measure ('In the last 12 months, was there any time you or anyone in your household ran out of food and did not have enough money to purchase more?').[45,47] Participants responded based on their experience in the previous 30 days in one study[47] and the past 12 months in the other.[45] Two studies asked participants about the impact of COVID-19 on psychological health however no standardised survey tool was used to measure this.[45,48]

Semi-structured interviews were the most common qualitative method used ($n = 4$)[43,45,46,48] followed by online workshops ($n = 1$)[42] and focus groups ($n = 1$).[44] Qualitative measurements of food insecurity involved all domains of food security: food availability,[42,43,45] accessibility,[42,43,45,46,48] affordability,[42–45,48] stability,[43,48] acceptability,[42,45] utilisation/

TABLE 1 Study and demographic characteristics of participants in included studies that investigate the prevalence of COVID-19 on food security in Australia ($n = 9$)

Author, state	Aim	Study design	Data collection methods	Participants	Sample size	Age	Gender	Other demographic characteristics
Brown et al.[46] Australia	To identify the impacts of learning at home during COVID-19 for vulnerable young Australians	Cross-sectional, mixed methods	Online survey and interviews (April 2020)	School students: preschool in the year prior to full time school, up to Year 12	Survey: $n = 70$; interviews: $n = 51$	N/R	N/R	N/R
Callis et al.[48] WA	To explore experiences of the COVID-19 pandemic, its restrictions, and its early economic and social impacts	Longitudinal, mixed methods	Surveys over 2 years (baseline, wave 2, and COVID-19 supplement between May and July 2020) and fortnightly interviews for a year	Entrenched disadvantaged families[a] in Perth	Completed COVID-19 supplement survey: $n = 158$	N/R	72% female	Aboriginal and Torres Strait Islanders: 20%; Had dependent children: 54%; Employment status: 19% employed in the week prior to survey; 13% unemployed but actively seeking and able to work; 68% not in labour force; Government assistance: 89% received at least one payment in the last 12 months
Craven and Mey[43] NSW	To identify the impact COVID-19 had on the community food sector within the Greater Sydney and Illawarra region and propose mitigation strategies	Cross-sectional, qualitative	Semi-structured interviews (August 2020)	Representatives from four community food organisations (OzHarvest, Rozelle Neighbourhood Centre, Community Greening and Food Fairness Illawarra)	$n = 4$ (one interviewee for each organisation)	N/R	N/R	N/R
Follent et al.[44] NSW	To show evidence to inform conversations on Aboriginal health issues in response to COVID-19 and beyond	Cross-sectional, qualitative	3 group discussions (August–September 2020)	Aboriginal community members from across NSW (Eora, Wilyakali, Bundjalung, Yuin and Gumbaynggirr lands)	$n = 12$	N/R	N/R	N/R
Foodbank Australia[45] Australia	To identify the impact of COVID-19 on Foodbank and its participants experiencing food insecurity	Mixed method (cross-sectional survey and interviews, longitudinal surveys)	A cross-sectional online survey (June–July 2020), 5 pulse surveys (monthly between April and	Individuals experiencing food insecurity (cross-sectional survey and interviews), charities and	Cross-sectional survey: *n = 1001;* Pulse surveys:	18 years and older	50% female	N/R

TABLE 1 (Continued)

Author, state	Aim	Study design	Data collection methods	Participants	Sample size	Age	Gender	Other demographic characteristics
			September 2020), in-depth phone interviews (August 2020)	community groups providing food relief (pulse surveys and interviews)	*n = 500* on average per survey; Interviews: *n = 9*			
Kent et al.[47] Tasmania	To determine the prevalence and socio-demographic predictors of food insecurity during the COVID-19 pandemic	Cross-sectional, quantitative	Online survey (May–June 2020)	Adult Tasmanian residents	*n* = 1170	18 years and older (68% over 46 years)	77% female	Aboriginal and Torres Strait Islanders: 2%; disability: 22% with disability; rurality: 28% rural; education: 67% bachelor's degree or higher; residency: 2% temporary residents; relationship status: 53% married; household status: 43% couple with no dependents, 28% couples with dependents, 6% single parent, 18% living alone, 5% other; primary shopper: 82%; household income per year: 21% less than AUD 40 000, 23% AUD 40 000–80 000, 43% more than AUD 80 000
McKay, Bastian and Lindberg[41] Victoria	To explore the impact of the COVID-19 pandemic on the emergency and community food sector and food insecure populations that use food aid	Cross-sectional, quantitative	Online survey (closed- and open-ended questions, May to June 2020)	Emergency and community food providers: pantries, soup kitchens, social enterprises, foodbanks and similar programs that provide free or subsidised food	101 agencies	N/R	N/R	Location: 64% in the greater metropolitan area; eligibility requirements: 61% required no proof of needing of food relief; number of clients accessing service: 52% 50 or less, 46% more than 50; allowed frequency of access: 24% less than weekly, 71% weekly or more; type of emergency food provided: 82% food parcels, 49% pre-prepared

(Continues)

TABLE 1 (Continued)

Author, state	Aim	Study design	Data collection methods	Participants	Sample size	Age	Gender	Other demographic characteristics
								meals, 44% food pantry, 40% vouchers, 14% cooking classes; primary population: 89% families, 69% people experiencing homeless, 65% people with disability, 60% migrants, 49% young people and children, 36% Aboriginal and Torres Strait Islanders, 15% older people, 81% serve several population groups
McKay and Brain[40] Victoria	To explore how emergency and community food aid providers in the Geelong region were impacted by the Covid-19 pandemic (including client needs, problems with demand and implications)	Cross-sectional, quantitative	Online survey (closed- and open-ended questions, November to December 2020)	Emergency food aid providers in the Geelong region	15 agencies	N/R	N/R	Type of providers: community organisations (40%), religious organisations (26%), and/or welfare and non-profit organisations (53%)
Whelan et al.[42] Victoria	To explore the impact of COVID-19 on food supply and purchasing behaviour in a rural supermarket in a rural Australian community	Cross-sectional, qualitative	Online workshops (June–July 2020)	Managers (managing director, operations manager and buyer/ operations manager) and regular customers from a rural supermarket in Victoria	$n = 36$ (manager: $n = 3$, customer: $n = 33$)	Over 18 years	56% female in customers, all male in managers	N/R

Abbreviations: AUD, Australian dollars; N/R, not reported; NSW, New South Wales; WA, Western Australia

[a] 'Families' = single person or an extended related (or unrelated) group of people.

TABLE 2 Summary of included studies that reported on the prevalence of food insecurity and factors related to changes in food security in Australia during COVID-19

	Primary outcomes	Secondary outcomes			
Author, state	**Prevalence of food insecurity**	**COVID-19-related job change**	**COVID-19-related income change**	**Sociodemographic factors associated with changes in food security**	**Other factors related to the change in food security**
Brown et al.[46] Australia	Most respondents concerned about 'lack of food'	N/A	N/A	*Newly food insecure children and young people*: due to COVID-19 and related extreme stress	*School closures*: →[a] loss of school breakfast program which majorly contributes to children and adolescents' nutritional needs nationally
Callis et al.[48] WA	*Limited access to food services*: 44.3% sought food services during COVID-19; 50% whose access to food services was stopped altogether by COVID-19; 63.9% reported changes to methods of accessing food services (paused or modified delivery mode such as providing pre-packed food parcels); 37.9% chose not to access or not able to access food services every time when they needed to; 43.3% who accessed food services reported it met their needs a bit or much less than before the pandemic	*COVID-related job changes*: The COVID-19 restrictions caused significant job losses and business closures (e.g., restaurants and cafes); 11.5% reported that they had been stood down or retrenched due to the pandemic; some industries needed to expand their work force due to ↑demand; of those who were employed, 13.3% got their current job and 6.7% got more hours in a job they already had	*Government financial support*: 33.3% received the JobSeeker payment, only one received JobKeeper payment; 50.6% received coronavirus supplement; 27.8% reported that the coronavirus supplement allowed them to afford enough food and ↑ the meal quality	N/A	*School closures*: contributes to food insecurity for children. *Cost of living*: food and bills (rent, utilities, debt repayments, car registration, and car repairs) were the most common expenditure. *Mental health*: Family members in this study had higher rates of depression and/or anxiety symptoms for most to all of the time (38.1% during the week prior to the survey) than the general Australian population (17.1% during the pandemic)
Craven and Meyer[43] NSW	All food relief organisations were negatively impacted by COVID-19; ↑ (S) in clients accessing food relief. ↓ *Availability*: ↓ (S) food at food relief; ↓ (S) food donated by supermarkets due to low supply caused by panic buying. Agencies primarily reliant on supermarket donations were most affected	*Food relief staff changes*: ↓ (S) in food charity volunteers—the most common reason was volunteers among the elderly (it was their best interest to avoid face-to-face contact with people during the pandemic). ↑ In volunteers at some points (attracting assistance from those who have lost their jobs)	*Government financial support*: Previous food relief recipients who received Centrelink benefit payments pre-COVID withdrew from food relief. Additional COVID supplement payments → more people were able to buy food directly from supermarkets instead of accessing food relief	*Newly food insecure*: families, people who lost jobs due to COVID-19, international students and the elderly	N/A

(Continues)

TABLE 2 (Continued)

	Primary outcomes	Secondary outcomes			
Author, state	**Prevalence of food insecurity**	**COVID-19-related job change**	**COVID-19-related income change**	**Sociodemographic factors associated with changes in food security**	**Other factors related to the change in food security**
Follent et al.[44] NSW	↑ *Food insecurity for some Aboriginal & Torres Strait Islanders* (based on community members' lived experience and anecdotal community feedback). ↓ *Affordability*: Price ↑ in local shops in some rural and remote areas → forced to buy cheaper (and often less healthy) options	N/A	N/A	*Minority groups within Aboriginal communities, (S) affected by COVID-19*: people with existing chronic conditions, people with disabilities, the homeless, people living in rural and remote areas, and people identifying as lesbian, gay, bisexual, transgender, queer, asexual and questioning	*Fear of going large shopping centres due to the fear of catching COVID-19*
Foodbank Australia[45]Australia	↑ *Prevalence of food insecurity*: 28% Australians experiencing food insecurity in 2020 did not experience it pre-COVID-19; 43% food insecure Australians went a day without eating at least once a week in 2020 compared to 30% in 2019; 61% of food insecure Australians accessing food relief since COVID-19; 31% food insecure Australians sought food relief at least once a week in 2020 compared to 15% in 2019. ↓ *Availability*: 81% of charities said demand for food relief has become more erratic and unpredictable since COVID-19. ↓ *Affordability*: 80% Australians receiving JobSeeker expect an AUD 300 payment cut after government payments are rolled back would mean they have to skip meals and buy less fruit and vegetables. ↓ *Accessibility and acceptability*: 39% of food insecure Australians in urgent need of help did not access food relief during the pandemic.	*COVID-19-related job loss*: Retail and accommodation industries were most impacted, accounted for most of casual workforce	*Government financial support*: 45% of food insecure Australians were getting assistance but needed more; 12% needed government assistance for the first time; of food insecure Australians receiving or needing assistance, only 38% felt the assistance helped their situation a lot; 62% did not receive help they need (37% needed additional assistance, 21% ineligible, 4% found it too difficult to apply)	*Age*: 65% of food insecure Australians aged 18–25 years went hungry at least once a week, 25% in 56–74 years; 25% in aged 75 years and older. *Traditional food relief clients need assistance more often during the pandemic*: Low-income families, unemployed, single-parent families, the homeless and people with mental illnesses. *Newly food insecure*: 39% charities saw ↑ in international students seeking food relief. 69% saw ↑ in newly unemployed casuals seeking food relief since COVID-19	*Mental health*: 53% food insecure Australians had decline in mental health since COVID-19: stress (49%), depression (46%), anxiety (41%) and sadness (39%). *Cost of living*: Main reason for the inability to afford food: 41% unexpected or large bills, 35% rent and mortgage payments

TABLE 2 (Continued)

Author, state	Primary outcomes: Prevalence of food insecurity	Secondary outcomes: COVID-19-related job change	Secondary outcomes: COVID-19-related income change	Secondary outcomes: Sociodemographic factors associated with changes in food security	Secondary outcomes: Other factors related to the change in food security
	Barriers to seeking assistance: thinking others more in need (33%), embarrassment (33%), shame (30%)				
Kent et al.[47] Tasmania	↑ *Prevalence of food insecurity*: 26% between late April to early June 2020 (12.3% marginal food security, 10.1% low food security, 3.7% very low food security). Higher than 2019 Tasmanian prevalence (6.2%) and national prevalence of (4%)	*COVID-related job change*: 34.6% had COVID-related job change; these people had a 75% ↑ in the odds of experiencing food insecurity compared to those not impacted. (S) higher proportion of those with COVID-related job change was in low (17%) and very low food secure groups (5%)	*COVID-related income loss*: Independently associated with higher odds of food insecurity; 34.2% had COVID-related income loss; 65% of those who had lost over 75% of their income had some degree of food insecurity; compared with who did not lose income, respondents who lost 25%–49% of income were twice more likely to be food insecure, who lost above 75% were seven times more likely to be food insecure. *Government financial support*: 14% received government support payments; receiving JobKeeper—20% more likely to be food insecure than employed without receiving government support; receiving JobSeeker—3.5 times more likely to be food insecure than employed without receiving government support	*Respondents with younger age, living in rural areas, with disability, lower education levels, lower income, and living with dependents are more likely to experience food insecurity during COVID-19*	N/A
McKay et al.[41] Vicotria	↑ *Food insecurity and ↓ availability*: ↑ in number (41.6%) and variety of people seeking food relief → food shortage at emergency food providers; 36.6% reported ↓ in people seeking food. 50.5% provided services to more people, 40.6% reported regular clients using service	N/A	*Government financial support*: 34.7% reported JobKeeper/JobSeeker has been helpful; 33.7% found no change; Concerned about the reduction or termination of government support and this may worsen supply/demand imbalance	*Demographic change in food insecure*: ↑ in international students (27.7%), people on temporary visas, and people ineligible for government support	*Loss of food relief staff and social distancing restrictions*: 76.2% lost volunteers due to age (>65 years) or the way of the service provided food aid

(Continues)

TABLE 2 (Continued)

Author, state	Primary outcomes	Secondary outcomes			
	Prevalence of food insecurity	COVID-19-related job change	COVID-19-related income change	Sociodemographic factors associated with changes in food security	Other factors related to the change in food security
	less frequently, 28.7% reported more frequently. *Accessibility to food relief*: 37.6% reported reduced operation hours; 15.8% extended operation hours; 40.6% extended service types; 30.7% temporarily closing or suspending services despite ↑ demand for food relief. *Nutritional requirements*: Most food relief agencies able to get at least half of required foods, but others reported changes to the food quality and quantity; 35%–45% unable to provide sufficient food in each of the nutritious food groups. More storage or freezer space needed. *Food preferences/culturally appropriate*: 55.4% unable to source quality foods; 22.8% unable to source food for specific cultural groups, 21.8% unable to source food for dietary requirements				
McKay and Brain[40] Victoria	↑ *Food insecurity*: 40% reported ↑ in people accessing food relief, 33% reported ↓; 47% reported ↑ use by regular clients. ↓ *Availability at food aid providers*: 71% said COVID-19 impacted food supply due to panic buying, upstream supply issues and challenges preparing and transporting food. ↓ *Accessibility*: 46% unable to assist people at some point	*COVID-19-related food relief staff losses*: 75% lost volunteer or paid staff due to the pandemic. Most operating with 1–2 paid staff, and mainly volunteers	*Government financial support*: 60% reported government support had not been helpful; Some reported ↓ in clients due to temporary government financial support. *Lack of food relief funding*: 66% food relief agencies funded via philanthropic funding with only modest funding changes; 20% received extra COVID-19 government funding	*Demographic of main food relief recipients* ↑ in people from casual/unstable industries and international students seeking food relief. 40% reported ↑ in food relief for children	*COVID-19 government restrictions*: 60% said restrictions affected client's access to food relief services and operation of many services (87%): 40% affected by physical distancing restrictions, 27% by capacity/density limits, 20% by close of business and stay at-home orders; Limits ↓ number of clients allowed inside, client/staff

TABLE 2 (Continued)

	Primary outcomes	Secondary outcomes			
Author, state	**Prevalence of food insecurity**	**COVID-19-related job change**	**COVID-19-related income change**	**Sociodemographic factors associated with changes in food security**	**Other factors related to the change in food security**
	this year due to lack of income and ↑ demand; 75% changed operations (close services, change service delivery to takeaway, delivery or phone assessments), 32% served more people, 14% extended service types, 18% temporarily closed or suspended services, 14% reduced operation hours, 7% extended hours. *Nutritional requirements/food preferences/culturally appropriate*: ↓ quality and quantity of food available at food aid providers; 57% had difficulty getting enough quality food, 29% had difficulty acquiring food for people with dietary requirements, 14% had difficulty obtaining cultural foods				interaction, community meals and meal deliveries
Whelan et al.[42] Victoria	↓ *Availability*: ↑ demand for food, insufficient supply, product limits. Customers stockpiling, shopping more frequently. ↓ *Accessibility*: One supermarket in the town and travel restrictions → ↑ online shopping. ↓ *Affordability*: Alternate supply logistics/suppliers → price ↑. *Acceptability*: No marketing/promotions and price ↑, yet customers still shop locally due to travel restrictions and fear. *Nutrition requirements/preferences/cultural appropriateness*: Customers	N/A	N/A	N/A	*Fear of COVID-19 and/or no food*: Caused by government and media messages and product limits → ↑ demand for food *Alternate suppliers and supply logistics and staff working longer hours to ↑ food supply.* *Lobbying by major chains*: negatively impacts food availability *Price ↑ and no promotions.* *COVID-19 government restrictions*: → more time for cooking, more meals eaten at home → larger basket size, more frequent

(Continues)

TABLE 2 (Continued)

	Primary outcomes	Secondary outcomes			
Author, state	**Prevalence of food insecurity**	**COVID-19-related job change**	**COVID-19-related income change**	**Sociodemographic factors associated with changes in food security**	**Other factors related to the change in food security**
	with dietary/health requirements more likely to use strategies (online shopping, liaising with friends/family to shop for them and changing frequency of shopping)				shopping, ↓ food availability and diet changes (e.g., not buying discretionary food); Capacity limit → restaurant closure, ↑ demand and pressure on local supermarket.

Abbreviations: AUD, Australian dollars; N/A, not Applicable; S, significant; ↑, increased; ↓, decreased; NSW, New South Wales; WA, Western Australia.
[a]Caused/lead to.

nutritional requirements,[42,45,46] food preferences[42,45] and cultural appropriateness.[43]

Study findings are listed in Table 2 and include the prevalence of food insecurity based on the domains of food security and secondary outcomes: COVID-19-related job and income changes and sociodemographic factors related to changes in food security.

Two studies quantitatively measured the prevalence of food insecurity; the Kent et al. study which used a modified version of the six-item US Household Food Security Survey Module to survey 1170 Tasmanian adults and the Foodbank report which involved a cross-sectional survey and five pulse surveys with 1001 members of the Australian public and food relief organisations.[45,47] Both reported higher percentages of food insecurity in Australia during COVID-19 compared to prior to the pandemic.[45,47] Kent et al. reported the prevalence of food insecure Tasmanian adults to be 26% between late April and early June 2020 with 10.1% and 3.7% in the low and very low food secure categories, respectively.[47] Fourteen percent of respondents were experiencing severe food insecurity and were regularly running out of food, going hungry and unable to afford balanced meals in the previous month.[47] This was substantially higher than pre-pandemic levels which were 6.2% in Tasmania and 4%–14% nationally, although the prevalence in Kent et al. study was measured by using a six-item tool and the prevalences prior to the pandemic were derived from a single-item question.[31,47,49] However, Kent et al. assert that when asked the same single item question in her study the response indicated more than 20% were food insecure.[47] Despite using a single item measurement tool prone to underestimation,[50] Foodbank found the prevalence of food insecure Australians going a day without food at least once a week to be even higher at 43% in 2020 compared to 30% in 2019.[45]

A demand and supply imbalance caused by a large increase in demand for food resulted in widespread unavailability of food.[40–48] Physical access to food outlets and food relief was found to be impaired in rural areas.[40,42] At the beginning of the pandemic (June – September 2020), studies conducted by Whelan et al. and Follent et al. noted an increase in food prices in rural Australia and Aboriginal NSW settings representing a reduction in food affordability for Australians living in these geographical areas who may have already been experiencing financial challenges.[42,44] In response, consumers stockpiled and shopped more frequently which added to the demand on food providers.[42] Stockpiling and limits on the quantity of a product able to be purchased in a single transaction hindered the access to food, especially for larger families, low-income

households and/or rural residents.[47] Strategies used to cope with changes in food security in rural areas included eating less, buying cheaper foods, liaising with others to shop for them, shopping online, accessing food banks or government assistance, or buying smaller quantities of food at a higher unit price.[42]

In addition to food-insecure populations previously noted the COVID-19 pandemic saw new demographics experiencing food insecurity for the first time. Four studies noted rising numbers of international students, people from casual/unstable industries, and those who lost jobs due to COVID-19 experiencing food insecurity and seeking food relief more frequently during the pandemic (Table 2).[40,41,43,45] Two studies also reported an increase in children experiencing food insecurity and accessing food relief during the pandemic.[40,46]

Food relief organisations reported their operations being negatively impacted by COVID-19 and difficulties coping with demand.[40,41,43,45] Foodbank,[45] a major food relief organisation, reported a 61% increase in Australians accessing food relief since COVID-19 with 31% seeking food relief at least once a week in 2020 compared to 15% in 2019 with similar findings from two other studies.[40,41] One-third of previous food relief recipients opted not to access food relief during the pandemic and food insecure people and families did not always access relief when needed.[40,41,48] COVID-19 also necessitated changes to operations by emergency providers that included closures during lockdowns, reducing operating hours, phone assessments and providing take-away to minimise social interaction while serving more people.[40,41,43,45] Some organisations extended operating hours but this was less common.[40,41] Despite these changes, about half of the users of food relief organisations in the 100 Families study in Western Australia indicated that their access was stopped during COVID-19 and services no longer met their needs the same as pre-COVID-19.[48]

A reduction in quantity and quality of food available at food outlets and food relief providers reduced the ability to eat balanced meals that met nutritional requirements or cultural food preferences during the pandemic.[40,41,43,47] Nearly, half of the food relief agencies were unable to provide sufficient food in each of the five food groups (e.g., 44% reported insufficient quantities of vegetables).[41] Many food relief agencies reported difficulties in sourcing quality foods (55%), foods for special dietary requirements (29%) and cultural groups (23%).[40,41]

Table 2 also shows the factors influencing the changes in food security status during the pandemic which included government restrictions, changes to food suppliers and supply logistics, fear of COVID-19 transmission, product limits, COVID-related job and income changes, cost of living, receiving government financial support, difficulties accessing welfare or food relief, and stigma associated with food banks.[40–48]

Changes in employments such as becoming retrenched, unemployed or having reduced work hours, and income changes appeared to be major drivers of food insecurity during COVID-19.[47,48] Experiencing a COVID-related job change increased the odds of food insecurity by 75% compared to those who had not,

TABLE 3 Themes that show the changes in food security, contributing factors and effects of the changes among Australians during COVID-19 from studies using a qualitative approach

Themes	Brown et al.[46]	Callis et al.[48]	Craven and Meyer[43]	Follent et al.[44]	Foodbank[45]	Whelan et al.[42]
Food supply and demand imbalance	√	√	√	√	√	√
Increase in food prices		√		√	√	√
Cost of living		√			√	
Fear of COVID-19 or running out of food		√		√		√
Feeling shame and/or embarrassment accessing food relief		√			√	
Impact of at-home learning on food security	√					
Demographic changes in the food insecure	√		√	√	√	
Impact of government welfare payments		√	√			
Coping mechanisms						√

TABLE 4 Selective quotations to show the changes in food security, contributing factors and effects of the changes among Australians during COVID-19 from included studies

Themes	Quotations from articles
Food supply and demand imbalance	'Increase in demand for our food relief meant donated surplus food was insufficient to meet demand. We have been purchasing fresh food from a local wholesaler for the past month to supplement donated surplus food'. (Food relief provider, Victoria)[41] '...the channels from which you [customers] could get food had diminished, so supermarkets became the main outlets for that and in addition to that and because of the panic buying, people were filling their pantries and buying more product'. (Supermarket manager, Victoria)[42]
Increase in food prices	'Increase in government payments has resulted in the one and only shop in community providing food jamming their prices up. The price of food and water is beyond compare when you are paying $10 for a loaf of bread. Because of COVID-19, people do not want to come into town to do their shopping'. (Aboriginal community member, NSW)[44] 'Because the state of Victoria was declared a disaster so all food from food bank Victoria was diverted to Red Cross for emergency hampers. This left much of the pasta and ambient goods that we were normally able to access unavailable for food aid agencies. We had to purchase these products through other means, thus putting budgets under pressure'. (Food relief provider, Victoria)[40]
Cost of living	'Rents have increased locally keeping the situation very similar'. (Food relief provider, Victoria)[40]
Fear of COVID-19 transmission	'When Geelong was in the first and second wave, [agency] began a meal delivery service to ensure those that needed meals received them. Many of our clients that attend the community meal stayed home, instead of coming to the foodbank due to fear of COVID. In the beginning, we had to close for about 3 months'. (Food relief provider, Victoria)[40]
Feeling shame and/or embarrassment accessing food relief services	'(Sometimes I do not seek food relief even if we have run out) because it's kind of embarrassing. I feel embarrassed and like I'm not a good enough parent because I cannot afford food'. (Single mother, SA)[45] 'What we are seeing is they cannot be the breadwinner in the home and they cannot feed their families and they feel really bad not being able to provide for them. We have seen a lot more coming in and asking for it. They're really embarrassed about asking for it, and that's really sad. It's really hard for men to come and ask, women find it easier'. (Founder of Survivors R Us, NSW)[45]
At home learning and reduced access to school breakfast programs	'Children we work with also receive their breakfast from school, as they do not receive this at home, although not an educational requirement, these support structures that traditional schooling provides equip a child's opportunity to learn'. (Non-Government Organisation, Australia)[46] 'Some (families) that are really struggling because they have got no work...They will be really, really under the pump to provide food for their children because they have got to still pay for the basics. And when you have got children under your feet and at home all day, they eat a lot more than when they are at school'. (School-based staff, Australia)[46]
Demographic shift: Emerging food insecure groups	'We started to see another layer on top of our regular clients, of people who had not accessed food relief before and were doing okay before the pandemic. Some had two working people in their families and then they no longer had jobs... because they were thrown into that situation, the levels of anxiety and fear rose, people were very worried...' (Reservoir Neighbourhood House, Victoria)[45] 'It's been very, very hard times, since May this year. I was doing my master's in information technology and I'm spending almost $70 000 on university for 2 years. I graduated in mid-July and have not been able to find employment since then... and I do not know who to ask or who to approach, because I'm not eligible for any kind of funding from the government... My parents have supported me until now. It's really hard for them to support me now... this was the first time I've had to

TABLE 4 (Continued)

Themes	Quotations from articles
	worry about food. I came to Australia in July 2018, and before that, I was living in India with my parents. It's a first for me.' (Recently graduated international student, Victoria)[45]
Impact of government welfare payments	'Well it's made it a lot easier, I can feed the girls a lot better, I have been able to supply more balanced meals'. (Food insecure family member, WA)[48] 'We received additional funding due to impact of COVID. We have had more funding for the purchase of emergency food from local government and philanthropy but have lost income from our traditional voucher system as referring agencies have closed operations and lost income from their op shops, etc. We have received less general donor and local business support'. (Food relief provider, Victoria)[40]
Coping mechanisms	'I think it's because I had a bit more time and there's been a lot of talk about food recipes, so it's probably just motivated me'. (Rural supermarket customer, Victoria)[42] 'I remember going in when Covid started and there was absolutely none [chocolate] of them were on offer and I suppose that's good because. .. you probably should not eat it, but you know, you have got [to] treat yourself sometimes and I noticed that none of them were on offer and I did not actually buy any'. (Rural supermarket customer, Victoria)[42]

resulting in significantly more of these people in low and very low food security groups.[47] Independently of other factors (including household income), COVID-related income loss was associated with a significantly increased risk of food insecurity.[47] Some people were recently employed or received more working hours due to COVID-19-related demand; however, this proportion was much smaller (lower than 15%).[48]

Regarding the effectiveness of the government support payments for alleviating financial stress and food insecurity, some Australians found it helpful but there were concerns about how to cope with the situation after payments end.[40,41,43,45,48] The type of government payments appeared to be a factor. Those receiving the JobKeeper payment were 20% more likely to be food insecure and those receiving JobSeeker were 3.5 times more likely to be food insecure than employed people who were not receiving financial benefits.[47] Among JobSeeker recipients, 25% experienced marginal food security and a further 27% experienced low and very low food security.[47]

From the two studies measuring sociodemographic factors ($n = 2671$), increasing age was protective against food insecurity with the odds of experiencing food insecurity reducing by 16% with every decade of life.[45,47] There were significantly more Aboriginal and Torres Strait Islander people, people with a disability, permanent and temporary residents, single-person households (never married, separated or single parents), low-income households (less than AUD 40 000 per year) and people residing in rural areas experiencing marginal, low or very low food security than their counterparts.[47] Notably, food insecurity was still evident in respondents with the highest incomes (above AUD 100 000 per year).[47] No significant difference was found between sexes in food-secure categories but more females reported very low food security (4%) than males (1%) in one study only.[47]

The themes synthesised from studies using a qualitative approach are listed in Table 3 and included nine themes: food supply and demand imbalance, rising food prices, cost of living, fear of COVID-19 and running out of food, feeling shame and/or embarrassment accessing food relief, impact of at-home learning on food security, demographic changes in the food insecure, impact of government welfare payments on food security, and coping mechanisms. Table 4 presents representative quotations from studies that used qualitative approaches and open-ended questions to investigate the impact of COVID-19 on food security.

4 | DISCUSSION

The findings of this review indicate increases in the prevalence of food insecurity in Australia since COVID-19 highlighting the vulnerability of the Australian food system and the urgency to address risk factors contributing to food insecurity.[40–48] COVID-19 has had profound effects on food supply and demand resulting in negative

changes to all food security domains including physical and social accessibility, affordability, availability and stability.[40–48]

The government-enforced travel restrictions, border closures and lockdowns disrupted food transport and supply, and food agencies reported these limited physical access and availability of nutritious and acceptable food.[40–48] Consumers began stockpiling food due to stay-at-home restrictions and shopping more frequently which compounded access problems that impacted the food security of Australians across all income brackets.[40,42,45,47]

Multiple economic barriers to food security during COVID-19 were identified and included higher food prices, no price promotions aimed to incentivise customers to purchase certain food products (e.g., discounts) and job or income changes. The association between unemployment and/or low income with higher food insecurity is consistent with studies conducted in the United States and Canada.[47,51–53] In the United States, 31% of those who had become unemployed due to COVID-19 in February 2020 were food insecure, and subsequently, 33% of these individuals ate less due to financial constraints.[53] In households where there was more than one member who lost their job or income, 72% were food insecure (59% if only one household member lost a job or income).[52] In Canada, nearly 25% of job-insecure individuals experienced food insecurity.[51] Changes in the food environment and financial security are therefore likely to contribute to impaired financial access, availability and affordability of food and subsequently food security.

Due to the physical and financial barriers to food access, the ability to consistently obtain preferred food of sufficient nutritional quality was reduced.[40,41,44,45] Lower-income individuals were forced to buy cheaper and often less nutritious options because they were unable to stockpile or purchase expensive alternatives.[44,45] In Victoria, the percentage of people relying on lower cost, less nutritious food options in May/June 2020 (23%) significantly decreased by the second wave of the pandemic in September 2020 (18%) suggesting that the financial ability to purchase food may have improved over time.[54]

This improvement could be related to the increase in income support payments in 2020 with some government welfare recipients, who were previously food insecure, finding the payments enabled them to afford enough and better quality food explaining why some previous food relief recipients withdrew from the food relief service.[40,43,48] A survey conducted by the Australian Council Of Social Service in May 2020 similarly reported that more than 80% of respondents could eat more regularly and 93% could afford fruit and vegetables when receiving the full coronavirus supplement.[55] The reduction in food insecurity in recipients of unemployment insurance was also observed in a longitudinal study conducted in the United States during the pandemic.[56]

For those who did not find government payments helpful, reasons included needing more financial assistance, ineligibility and difficulty to apply so they remained or became food insecure.[40,41,43,45,48] Cost of other living expenses such as rent, mortgages and medical costs was commonly cited as a reason for being unable to afford food.[40,41,43,45,48,55] It was reported that almost half of adult Australians were drawing on finite financial resources to manage household expenses reducing the money available for food.[57] This adds to the argument that higher income, which was associated with higher food security prior to the pandemic, continues to be protective against food insecurity by alleviating total living costs.[47]

A primary response to food insecurity in Australia has involved a reliance on food relief charities. COVID-19 has exposed the fragility of the food relief system as most food relief providers struggled to meet the increased demand with a diminished food supply.[40,41,43,45] This stems from their reliance on donations from supermarkets or larger food banks who were experiencing their own supply issues.[40,41,43] The access to food relief was hindered by eligibility requirements, difficulties in accessing online service updates, physical distancing restrictions, capacity limits, and closure of businesses and home deliveries.[40,48] Dramatic reductions in staff numbers, especially older volunteers who preferred to stay home due to increased susceptibility to COVID-19, had a major impact on food relief organisations being able to operate effectively and efficiently.[41] Food relief providers also experienced difficulties acquiring good quality food and appropriate food for dietary and/or cultural requirements which may exacerbate inequalities particularly for low income and ethnic minority groups.[40,41]

Despite increased need, some food insecure Australians chose not to seek food relief.[45,48] This could be a result of stigma associated with food assistance since common concerns about accessing food relief voiced by respondents included thinking others needed it more, embarrassment or shame.[45,48] Overall, the reduction in food quantity and quality, operational changes and compromised access to food relief may explain why a low percentage of recipients reported that the services met their needs.[40,41,43,48]

COVID-19 has exacerbated existing social inequities and created economic vulnerability for people who were previously food secure and are now experiencing income losses. During COVID-19, there was an increase in food

insecurity for international students, workers from casual or unstable industries, and the newly unemployed.[40,41,43,45] International students became more vulnerable during COVID-19 due to their ineligibility for government welfare, reduced financial support from family, and loss of part-time work.[45] Most casual workers were greatly impacted by COVID-19 and had less entitlements and working hours.[45,47] This may also explain the correlation between increased age and lower odds of food insecurity as older age groups are less likely to belong to these newly food insecure groups.[45,47] The potential increase in food insecurity among children could be attributed to school closures stopping access to free meals from school breakfast programs and only half of family members with children in the 100 families project being eligible for COVID-19 supplement payments.[46,48]

A strength of this scoping review is the synthesis of qualitative and quantitative evidence and inclusion of multiple perspectives including those from vulnerable groups. Findings of this review can be used to inform further research. Furthermore, the search strategy considered the multi-dimensional nature of food security enabling a comprehensive assessment of food security. This review also has some limitations. The number of studies located is small and diverse which makes generalisation difficult. For an even wider scope of grey literature, Google could also be searched. Due to the need for rapid responses and social distancing, convenience sampling and online data collection methods were used in some studies which may have introduced bias and prevented those without internet access from participating. In addition, as the search for articles to be included in the review was conducted at a single point in time, the findings reflect the state of food security at that time point so further investigation is recommended.

In conclusion, the increasing prevalence of food insecurity in Australia during the COVID-19 pandemic has highlighted vulnerabilities in the Australian food system and the urgent need to address factors contributing to food insecurity. Many casual workers and international students became food insecure for the first time due to the loss of income during COVID-19. Coping with food insecurity by purchasing cheaper but unhealthy food emphasises the importance of having sufficient nutritious food to achieve genuine food security. Since the pandemic is still occurring, further data collection of food security in Australia is vital to understand the prevalence and extent of food insecurity experienced at different stages of the pandemic. Future research should focus on changes to, and factors affecting, food security in newly food insecure groups, the impact of COVID-19 on diet quality, coping strategies for food insecurity, and the association between mental health and food security. In the short term, food aid providers would benefit from increased financial support for maintaining a sufficient food supply, better storage facilities, or mobile foodbanks to improve food access and availability. Food relief organisations could also implement strategies to increase the awareness of their services, reduce stigma and restore dignity to recipients.[45] Long-term strategies that address underlying factors of food security could involve policies that improve financial resources such as secure employment opportunities that pay living wages and sufficient welfare payments.[23,47] Finally, collaborations between communities and governments to create resilient urban and rural food environments are necessary for a food secure nation.[47]

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Serena Louie conducted the searches, study selection, data extraction and synthesis, and wrote the first manuscript draft. Yumeng Shi contributed to the study selection, data extraction, and the second manuscript draft. Margaret Allman-Farinelli contributed to the study design, study selection and synthesis of the results. All authors reviewed and revised the manuscript draft. The authors would like to acknowledge Monica Cooper, an academic liaison librarian at the University of Sydney for support in the development of the search strategy.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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REFERENCES

1. Keane D. Coronavirus is causing panic buying, but what does that mean for Australia's food security? *ABC News*, 16, 2020. www.abc.net.au/news/2020-03-16/coronavirus-is-not-a-threat-to-food-supply-experts-say/12058412.
2. Keane D. Coronavirus isn't causing Australia to run out of food—but why are shelves still bare? *ABC News*, 19, 2020. www.abc.net.au/news/2020-03-19/coronavirus-distribution-problems-for-supermarket-suppliers/12066684
3. Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). *Australian Food Security and the Covid-19 Pandemic*. ABARES; 2020. Accessed August 25, 2021. https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1030201/0

4. Australian Bureau of Statistics. One year of COVID-19: Aussie jobs, business and the economy. 2021. https://www.abs.gov.au/articles/one-year-covid-19-aussie-jobs-business-and-economy#:~:text=72%25%20of%20businesses%20had%20less,vacancies%2043%25%20below%20February%20figures. Accessed 25 August, 2021.
5. Pollard CM, Landrigan TJ, Gray JM, McDonald L, Creed H, Booth S. Using the food stress index for emergency food assistance: an Australian case series analysis during the COVID-19 pandemic and natural disasters. *Int J Environ Res Public Health.* 2021;18(13):6960.
6. Food and Agricultural Organization of the United Nations (FAO). International Fund for Agricultural Development, United Nations International Children's Emergency Fund, World Food Programme and World Health Organization. *The State of Food Security and Nutrition in the World 2020. Transforming Food Systems for Affordable Healthy Diets*. FAO; 2020. http://www.fao.org/documents/card/en/c/ca9692en
7. Jones A, Ngure F, Pelto G, Young S. What are we assessing when we measure food security? A compendium and review of current metrics. *Adv Nutr.* 2013;4(5):481-505.
8. Haseltine WA. What can we learn from Australia's Covid-19 response? *Forbes*. 2021. https://www.forbes.com/sites/williamhaseltine/2021/03/24/what-can-we-learn-from-australias-covid-19-response/?sh=4538f5c33a01
9. Shine R. WA has a 'go hard, go early' approach to COVID-19 lockdowns, but what is the pathway out? *ABC News*. 2021. https://www.abc.net.au/news/2021-07-18/wa-hard-lockdown-approach-pathway-out-of-covid/100301206
10. Melbourne: Celebrations as city exits sixth lockdown. *BBC News*. 2021. Accessed November 28, 2021. https://www.bbc.com/news/world-australia-58998418
11. Lathouris O. Northern beaches residents back to normal after lockdown lifted. *Nine News*. 2021. https://www.9news.com.au/national/coronavirus-northern-beaches-last-day-lockdown-restrictions-easing/bd683fb3-056c-48ea-bdab-dcef28f5d7f4
12. Klein A. Sydney comes out of 4-month lockdown after reaching vaccination target. NewScientist. 2021. https://www.newscientist.com/article/2293117-sydney-comes-out-of-4-month-lockdown-after-reaching-vaccination-target/
13. Australian Bureau of Statistics. Weekly Payroll Jobs and Wages in Australia, Week ending 2020. Accessed 25 August, 2021. https://www.abs.gov.au/statistics/labour/earnings-and-work-hours/weekly-payroll-jobs-and-wages-australia/week-ending-27-june-2020
14. Australian Taxation Office, Australian Government. JobKeeper Payment. 2021. https://www.ato.gov.au/General/JobKeeper-Payment/
15. Services Australia, Australian Government. Coronavirus Supplement. 2021. https://www.servicesaustralia.gov.au/individuals/services/centrelink/coronavirus-supplement
16. Klapdor M. *Australian Government COVID-19 Disaster Payments: a Quick Guide*. Parliament of Australia; 2021 https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp2122/Quick_Guides/COVID-19DisasterPayments
17. How much is the JobSeeker payment now and when does it end? *ABC News*. March 18, 2021. Accessed November 28, 2021. https://www.abc.net.au/news/2021-03-18/how-much-is-jobseeker-when-does-it-end-what-are-new-rules/13259460
18. Services Australia, Australian Government. JobSeeker Payment. Accessed August 25, 2021. https://www.servicesaustralia.gov.au/individuals/services/centrelink/jobseeker-payment
19. Phillips B, Narayanan V. *Financial Stress and Social Security Settings in Australia*. Australian National University; 2021.
20. Ramsey R, Giskes K, Turrell G, Gallegos D. Food insecurity among adults residing in disadvantaged urban areas: potential health and dietary consequences. *Public Health Nutr.* 2011;15(2):227-237.
21. Booth S, Smith A. Food security and poverty in Australia—challenges for dietitians. *Aust J Nutr Diet.* 2001;58(3):150-156.
22. Victorian Agency for Health Information. *Challenges to Healthy Eating– Food Insecurity in Victoria: Findings from the 2014 Victorian Population Health Survey*. Victorian Agency for Health Information; 2017.
23. O'Kane G. COVID-19 puts the spotlight on food insecurity in rural and remote Australia. *Aust J Rural Health.* 2020;28(3):319-320.
24. Government of South Australia. *South Australian Population Health Survey: 2019 Annual Report*. Government of South Australia. 2021. Accessed November 28, 2021. https://www.sahealth.sa.gov.au/wps/wcm/connect/1d18c141-d277-4bb5-bc28-99bfade9c36a/SAPHS+2019+Annual+Report+-+Adults.pdf?MOD=AJPERES&CACHEID=ROOTWORKSPACE-1d18c141-d277-4bb5-bc28-99bfade9c36a-nKQgb.G
25. Victorian Government. *Victorian Population Health Survey 2019: Summary of Results*. Victorian Agency for Health Information; 2021.
26. Australian Bureau of Statistics. Data from: Australian health survey: nutrition—state and territory results. 2015.
27. Bowden M. *Understanding food insecurity in Australia. CFCA paper no 55. Australian Institute of Family Studies.* 2020.https://aifs.gov.au/cfca/publications/understanding-food-insecurity-australia
28. Dombrovskaya MLT. *Health and Wellbeing of Adults in Western Australia 2019, Overview and Trends*. Department of Health; 2020.
29. Drakoulidou P, Drayton B, Shepherd L, Mihrshahi S. Sociodemographic factors associated with food insecurity: data from the 2003–2014 New South Wales Population Health Survey. *Public Health Nutr.* 2020;23(11):1857-1867.
30. Alice Spring Food Security Reference Group. *Alice Springs Food Security Needs Assessmen, 2019–2020 Part One of Three*. Alice Springs; 2020.
31. Department of Health, Tasmania. *Report on the Tasmanian Population Health Survey 2019*. Department of Health; 2020.
32. McKay FH, Haines BC, Dunn M. Measuring and understanding food insecurity in Australia: a systematic review. *Int J Environ Res Public Health.* 2019;16(3):476.
33. Butcher LM, O'Sullivan TA, Ryan MM, Lo J, Devine A. Utilising a multi-item questionnaire to assess household food security in Australia. *Health Promot J Austr.* 2019;30(1):9-17.
34. Fronek P, Briggs L, Liang J, Gallagher H., Doherty A., Charles B., McDonald S. Australian social work academics respond to international students in crisis during COVID-19. *Frontiers in Education*. March 17, 2021.doi: 10.3389/feduc.2021.637583
35. Seivwright AN, Callis Z, Flatau P. Food insecurity and socioeconomic disadvantage in Australia. *Int J Environ Res Public Health.* 2020;17(2):559.

36. Temple JB, Booth S, Pollard CM. Social assistance payments and food insecurity inAustralia: evidence from the household expenditure survey. *Int J Environ Res Public Health.* 2019; 16(3):455.
37. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol.* 2018;18(1):143.
38. Peters M, Godfrey C, McInerney P, Baldini Soares C, Khalil H, Parker D. Chapter 11: scoping reviews (2020 version). In: Aromataris E, Munn Z, eds. *JBI Manual for Evidence Synthesis*. Joanna Briggs Institute; 2020. doi:10.46658/JBIMES-20-12
39. Tricco A, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med.* 2018;169(7):467-473.
40. McKay F, Brain J. *Exploring the Capacities and Responses of the Community and Emergency Food Sector in the Geelong Region: Report 1*. Deakin University; 2020.
41. McKay FH, Bastian A, Lindberg R. Exploring the response of the Victorian emergency and community food sector to the COVID-19 pandemic. *J Hunger Environ Nutr*. 2021;16(4):447-461. doi:10.1080/19320248.2021.1900974
42. Whelan J, Brown AD, Coller L, et al. The impact of COVID-19 on rural food supply and demand in Australia: Utilising group model building to identify retailer and customer perspectives. *Nutrients.* 2021;13(2):417.
43. Craven C, Meyer E. *The Impact of COVID-19 on Food Insecurity in the Greater Sydney and Illawarra Region*. Macquarie University; 2020.
44. Follent D, Paulson C, Orcher P, et al. The indirect impacts of COVID-19 on aboriginal communities across New South Wales. *Med J Aust.* 2021;214(5):199-200.e1.
45. Foodbank Australia. *Foodbank Hunger Report 2020*. Foodbank Australia; 2020.
46. Brown N, Te Riele K, Shelley B, Woodroffe J. *Learning at Home during COVID-19: Effects on Vulnerable Young Australians*. Peter Underwood Centre for Educational Attainment, University of Tasmania; 2020.
47. Kent K, Murray S, Penrose B, et al. Prevalence and sociodemographic predictors of food insecurity in Australia during the COVID-19 pandemic. *Nutrients.* 2020;12(9):2682.
48. Callis Z, Seivwright A, Orr C, Flatau P. The impact of COVID-19 on families in hardship in Western Australia. In: Uniting WA, Wanslea WACOSS, eds. *The 100 Families WA Project (Anglicare, Centrecare, Jacaranda Community Centre, Mercycare, Ruah Community Services)*. The University of Western Australia (Centre for Social Impact and the School of Population and Global Health); 2020.
49. Australian Bureau of Statistics (ABS). *4364.0.55.009—Australian Health Survey: Nutrition—State and Territory Results, 2011–12*. ABS; 2015.
50. McKechnie R, Turrell G, Giskes K, Gallegos D. Single-item measure of food insecurity used in the National Health Survey may underestimate prevalence in Australia. *Aust N Z J Public Health.* 2018;42(4):389-395.
51. Men F, Tarasuk V. Food insecurity amid the COVID-19 pandemic: food charity, government assistance, and employment. *Can Public Policy.* 2021;47(2):202-230.
52. Wolfson JA, Leung CW. Food insecurity during COVID-19: an acute crisis with long-term health implications. *Am J Public Health.* 2020;110(12):1763-1765.
53. Raifman J, Bor J, Venkataramani A. Unemployment insurance and food insecurity among people who lost employment in the wake of COVID-19. Version 2. *medRxiv*. Preprint. 2020.10.1101/2020.07.28.20163618
54. VicHealth. *VicHealth Coronavirus Victorian Wellbeing Impact Study: Follow-Up Survey*. VicHealth; 2020.
55. Australian Council of Social Service. *'I Can Finally Eat Fresh Fruit and Vegetables' Survey of 955 People Receiving the New Rate of JobSeeker and Other Allowances*. Australian Council of Social Service; 2020.
56. Raifman J, Bor J, Venkataramani A. Association between receipt of unemployment insurance and food insecurity among people who lost employment during the COVID-19 pandemic in the United States. *JAMA Netw Open.* 2021;4(1):e2035884.
57. Thomsen A, O'Neill E, Martin Hobbs B, Solomon L. *COVID-19 and consumers: from crisis to recovery*. Consumer Policy Research Centre; 2020.

SUPPORTING INFORMATION

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REVIEW

Rural healthcare delivery and maternal and infant outcomes for diabetes in pregnancy: A systematic review

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Abstract

Aim: The aim of this systematic review was to examine the literature regarding rural healthcare delivery for women with any type of diabetes in pregnancy, and subsequent maternal and infant outcomes.

Methods: Eight databases were searched in September 2020, including Medline, EMCare, CINAHL, EMBASE, Maternity and Infant Care, Cochrane, Rural and Remote Health and Aboriginal and Torres Strait Islander Health bibliography. Studies from high-income countries in rural, regional or remote areas with interventions conducted during the antenatal period were included. Intervention details were reported using the template for intervention description and replication template. Two reviewers independently assessed for risk of bias using the RoB2 and ROBINS I tools.

Results: Three articles met the inclusion criteria: two conducted in Australia and one in the United States. A multidisciplinary approach was reported in two of the included studies, which were modified specifically for their respective rural settings. All three studies reported rates of caesarean section, birthweight (grams) and gestational age at birth as maternal and infant outcomes. One study was considered at moderate risk of bias, and two studies were at serious risk of bias.

Conclusion: There is a significant gap in research relating to healthcare delivery for women with diabetes in pregnancy in rural areas. This lack of research is concerning given that 19% of individuals in high-income countries reside rurally. Further research is required to understand the implications of healthcare delivery models for diabetes in pregnancy in rural areas.

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KEYWORDS
diabetes in pregnancy, gestational diabetes, healthcare delivery, models of care, rural health

1 | INTRODUCTION

Diabetes in pregnancy (DIP) is one of the most common conditions experienced in pregnancy.[1] It refers to pregnant women with a diagnosis of either type 1, type 2 or gestational diabetes mellitus (GDM). Globally, in 2019, an estimated 20.4 million or approximately 16% of births were adversely affected by DIP.[2] Of these, 84.6% were classified as GDM, 7.9% were from diabetes detected before pregnancy including type 1 or type 2 diabetes mellitus and the remaining 8.5% were diabetes types apart from GDM (including type 1 and type 2 diabetes) that were first detected in pregnancy.[2] GDM is the most rapidly rising diabetes category in Australia, with rates of diagnosis tripling over the last decade from 5% in 2008–2009 to 16% in 2017–2018.[3,4] In 2015, type 1 and 2 diabetes mellitus in pregnancy accounted for approximately 1% of all cases of DIP.[5]

Suboptimal glycaemic control in pregnancy is associated with an increased risk of a range of adverse maternal[5] and infant outcomes.[5–7] This disease burden extends past the perinatal period, with women who experienced GDM having a seven-fold increased risk of developing type 2 diabetes mellitus, typically within 5–10 years of their diagnosis.[8,9] The risk of both short- and long-term adverse outcomes can be minimised through the comprehensive management of DIP.[10–14] A reduction in adverse outcomes has been achieved in intervention studies with a focus on optimising glycaemic control through dietary advice, self-monitoring of blood glucose levels and pharmacotherapy as required.[12,13] A randomised controlled trial of usual care ($n = 473$) and specialised treatment ($n = 485$) for mild GDM showed significant reductions in birthweight, rates of shoulder dystocia, and caesarean delivery in the treatment group compared to the control.[13]

Internationally, management guidelines for DIP focus on the goal of strict glycaemic control with some variation in recommendations according to diabetes type and by country.[14–18] However, there are similarities in the recommendations in developed countries.[14–18] The first is the recommendation of close monitoring and regular contact with a specialist multidisciplinary team of allied health and medical professionals before delivery.[14,15,17,19,20] Second, women should be referred to a dietitian for individualised and culturally appropriate dietary advice,[14,15,17] and for those with GDM, this should occur within 1 week of diagnosis.[16,18] Self-monitoring of blood glucose levels is recommended for women with all diabetes types throughout pregnancy.[14,17,18] Lastly, medication initiation is to occur in women with GDM where blood glucose targets are not met with lifestyle change alone,[14,16,17] and insulin therapy is likely required in women with pre-existing DIP.[15–17]

It has been well established that access to health services is limited for people living in rural and remote areas compared to those in metropolitan areas.[3,21] There were only 11 doctors per 10 000 people in non-metropolitan America in 2018, compared to 31 per 10 000 in metropolitan areas.[22] In 2017–2018, the number of full-time equivalent clinical specialists was 143 per 100 000 population in major cities in Australia, compared to 22 per 100 000 in very remote areas.[21] This deficit extends to maternal health services globally.[23,24] The lack of specialised healthcare in rural areas contributes to the increased risk of adverse maternal and perinatal outcomes.[24–27] This risk increases further for women with DIP in rural areas, with 37.6% of babies born pre-term to mothers living in remote or very remote areas in Australia with DIP, compared to 17.8% of babies in major cities.[5]

The limited number of health professionals in rural areas relative to metropolitan areas means that metropolitan-based models of care may not be feasible in rural areas. However, there is a lack of research investigating the healthcare accessible to women with DIP in rural areas.[28] The disparity may be magnified when high-income countries, such as Australia and the United States, are compared to low- to middle-income countries, where lack of clinician expertise and resources result in further deficiencies in the diagnosis and management of DIP.[29–31] Previous studies investigating models of care have used cross-sectional methods such as surveys, with a lack of reporting on detailed model of care processes and subsequent health outcomes.[32–34] To date, there has been one review with a target population of women with pre-pregnancy diabetes mellitus.[7] This review addressed exposures and subsequent outcomes and focused on Australian studies only.[7] There are no known systematic reviews investigating healthcare delivery for women with DIP in rural areas. Therefore, the aim of this systematic review was to identify and describe the current characteristics of healthcare delivery models of care internationally for women with DIP in rural areas, and describe the relationship with maternal and infant health outcomes.

2 | METHODS

The protocol for this review was registered with PROSPERO International prospective register of systematic reviews [CRD42020209956]. A search strategy was developed in consultation with a research librarian. Key search terms relating to diabetes and pregnancy and rural, regional or remoteness were used. Limits included the English language and papers published from 1990 onwards. This year was chosen as a cut off so that interventions reflect recent management recommendations in line with DIP research and technology developments, such as self-monitoring of blood glucose levels.[35,36] An initial systematic search of eight databases was conducted in September 2020. Databases searched included Medline (Ovid), EMCare (Ovid), CINAHL (EBSCOhost), EMBASE (Ovid), Maternity and Infant Care (Ovid), the Cochrane Library, Rural and Remote Health (Informit) and Aboriginal and Torres Strait Islander Health bibliography (Informit). The reference lists of included articles were hand searched to identify any additional studies that met the selection criteria. The full Medline search strategy is available as Appendix I (online supplementary material).

Studies were considered for inclusion if the target population was women with type 1 or type 2 diabetes mellitus in pregnancy or GDM. Any intervention conducted or observed in a regional, rural, remote or otherwise defined non-metropolitan setting by the study's authors and in a high-income country as defined by the World Bank (2019) was included.[37] The search was limited to high-income countries so that healthcare resourcing was comparable, as healthcare challenges and priorities for rural populations in low-income countries can vary greatly compared to high-income countries.[29,31] Studies were included if both metropolitan and non-metropolitan populations were represented, but the outcomes for the non-metropolitan group were reported separately. Interventions conducted or observed in the antenatal period were considered eligible. Studies with any comparator, such as an intervention or control group or pre/post study design were included. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to report results based on these criteria.[38]

Primary outcomes were defined as any maternal or infant physical or biochemical outcome related to glycaemic control, due to the broad range of outcomes associated with poor glycaemic control during pregnancy.[39] Physical outcomes included those such as caesarean section, preeclampsia, APGAR score and birthweight. Biochemical outcomes included blood glucose levels, neonatal hypoglycaemia and diabetic ketoacidosis. Secondary outcomes were also reported, and included nutrition, medication, behavioural, exercise, mental health related and healthcare delivery outcomes.

The title and abstract of identified studies were screened for eligibility independently by two reviewers. Full texts were then screened independently against the inclusion and exclusion criteria. If two reviewers disagreed at either the title and abstract or full-text stage, a third reviewer resolved this conflict. A data extraction template was developed and standardised, to ensure all relevant information was recorded. Data extracted included study design, participant characteristics, setting, rural description, maternal and infant outcomes, study results and conclusions. The template for intervention description and replication (TIDieR) template was used to extract specific intervention details and replication data.[40] The first reviewer extracted the relevant information, and this was checked by a second reviewer. A quality assessment was conducted independently by two reviewers on studies that met the inclusion criteria using either the Cochrane RoB2 or ROBINS-I tools,[41,42] depending on study design.

3 | RESULTS

The results of the search strategy are detailed in Appendix II (online supplementary material) using the PRISMA flow diagram.[38] Database searches returned 3177 articles, with a total of 1827 articles after duplicates were removed. Following title and abstract screening, 272 articles were considered for full-text inclusion. Three articles were identified as eligible and were included in the review.

Study and participant characteristics are outlined in Table 1. Two studies were conducted in Australia,[43,44] and one in the United States,[45] with sample sizes ranging from 87 to 303. One study was a pre-post design,[44] another was a retrospective cohort study with a control group, and the other was a non-randomised controlled trial.[45] All studies included women with GDM and type 2 diabetes mellitus in pregnancy. The two Australian studies also included women with type 1 diabetes mellitus in pregnancy.[43,45] Two studies described their location as a rural area,[44,45] and one as a regional hospital.[43] None of the studies included a specific rural, regional or remote definition.

Details of the interventions provided in each paper are shown using the TIDieR template in Table 2. The overall goals of each study varied substantially. One study involved referral to a lactation consultant to encourage antenatal expression and storage of colostrum.[43] The goal of this intervention was to compare rates of neonatal hypoglycaemia in women with any type of DIP who expressed antenatal colostrum to those who did not. Murfet et al.[44] investigated the effect of a nurse practitioner-led model of care on maternal and infant outcomes. The final article described a modified version of the "Sweet Success" program where rural antenatal

TABLE 1 Location, study design, sample size, demographics and rural descriptors for observational and intervention studies for women with diabetes in pregnancy in rural areas

Authors, year	Country; locality	Study design	Sample size	Demographics (age, ethnicity, SES)	Diabetes type/s	Rural/regional/remote description
Murfet et al. (2014)[44]	Australia; North West Tasmania	Pre-post	261	Mean age 31 years Caucasian 84% Aboriginal and/or Torres Strait Islander 7% Index of Relative Socioeconomic Advantage and Disadvantage deciles 1–4 99%	Pre GDM 57.1% T1DM 13.4% T2DM 4.5% Unknown (suspected GDM) 25.0% Post GDM 87.9% T1DM 7.4% T2DM 4.0% Unknown (suspected GDM) 3.4%	Describes study location as a "rural locality"
Casey et al. (2019)[43]	Australia; North Queensland	Retrospective cohort study with control group	303	Intervention Mean age 30 years Caucasian 88% Aboriginal and/or Torres Strait Islander 3.8% Filipino 2.5% Control Mean age 29 Caucasian 73% Aboriginal and/or Torres Strait Islander 7.2% Filipino 8.1% SES not reported	GDM 96% T1DM and T2DM % not individually specified	Regional public hospital
Weiderman and Marcuz (1996)[45]	United States; far North California	Non-randomised controlled trial Control group: usual care at a multidisciplinary "Sweet Success" program site[48]	87	Intervention Women <20 y 5% Women 20–29 y 46% Women 30–39 y 49% Caucasian 79% African American 0% Native American 3% Asian 5% Other 13% Control Women <20 y 6% Women 20–29 y 43% Women 30–39 y 45% Women >40 y 6% Caucasian 82% African American 4% Native American 8% Asian 4% Other 2% SES not reported	Intervention GDM 100% Control GDM 96% T2DM 4%	Rural geographic area of 5000 square miles

Abbreviations: DIP, diabetes in pregnancy; GDM, gestational diabetes mellitus; SES, socioeconomic status; T1DM, type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus.

TABLE 2 Description of interventions provided to women with diabetes in pregnancy in rural areas using the template for intervention description and replication—checklist[42]

Author, year	Why? Rationale/theory/goal	What? Materials and procedures	Who provided? How and where?	When and how much?	Tailoring and modifications
Murfet et al. (2014)[44]	Investigate maternal and infant outcomes following the implementation of a nurse practitioner-led model of care	Management protocol for insulin initiation in GDM and referral to physician Insulin initiated by obstetrician/credentialed diabetes educator for women with GDM Same day dispensing of insulin from hospital pharmacy Women with type 1 or type 2 diabetes mellitus were referred to diabetes physician at initial consult Use of continuous glucose monitoring and after-hours diabetes nurse educator contact	Coordinated by diabetes nurse practitioner Multidisciplinary clinic with: - Credentialed diabetes educator - Dietitian - Antenatal nurse - Obstetrician Face-to-face at one private and two local public hospitals	Initial 30 min credentialed diabetes educator—individual Initial 30 min dietitian—individual Joint credentialed diabetes educator/dietitian 20 min individual reviews—fortnightly until 36 weeks gestation then weekly Midwifery and obstetrics reviews as required	Individualised for low resource region Patients with type 1 and type 2 diabetes mellitus frequency of visits tailored to glycaemic control, use of insulin and obstetric reasons Modifications not reported
Casey et al. (2019)[43]	To compare rates of hypoglycaemia in babies born to mothers who express antenatal colostrum and mothers who do not, to inform local protocols	All women with diabetes in pregnancy were referred to a lactation consultant Women were educated on how to express and store colostrum daily between 34–36 weeks until birth Women were given syringes and labels to collect and store colostrum	Lactation consultant (referred to following an education session by the diabetes educator midwife) Face-to-face at a hospital site	Not reported	Not reported
Weiderman and Marcuz (1996)[45]	Establish GDM care plan for rural primary perinatal providers including a triage system for surveillance, diagnosis and management	Provider training materials and education packets, blood glucose meters and associated supplies were provided to each project site Following GDM diagnosis, patients were triaged into varying levels of care by the pilot guidelines and protocols	Obstetrician, diabetes educator, dietitian, mental health counsellor team streamlined "Sweet Success" program guidelines for each site + triage protocols developed Travelling multidisciplinary team, including the diabetes educator, dietitian and counsellor, provided	Followed up on a weekly or biweekly basis	Guidelines from the "Sweet Success" program were modified by specialist clinicians for each rural project site Focus on individualised patient care within pilot guidelines and protocols Modifications not reported

TABLE 2 (Continued)

Author, year	Why? Rationale/theory/goal	What? Materials and procedures	Who provided? How and where?	When and how much?	Tailoring and modifications
		Patients recorded blood glucose levels 3–4 times daily using blood glucose meters and kept daily dietary and fasting urine ketone levels	on-site training for project site staff Staff that were trained at clinic sites were either nurse midwives, certified nurse practitioners or registered nurses Face-to-face in a rural clinic setting		

Abbreviations: DIP, diabetes in pregnancy; GDM, gestational diabetes mellitus.

care providers including nurse practitioners, nurse midwives and registered nurses were upskilled in the diagnosis and management of GDM.[45]

Two studies described multidisciplinary care approaches, tailored for use in low resource rural settings.[44,45] Murfet et al.[44] included a multidisciplinary team coordinated by a nurse practitioner and included a dietitian, diabetes educator, obstetrician and antenatal nurse.[44] At the initial clinic visit, women were seen by each of these professionals. Follow up visits were scheduled fortnightly as joint consults with the dietitian and diabetes educator, with review by the antenatal nurse and obstetrician as necessary. Weiderman and Marcuz[45] described a visiting team consisting of a dietitian, diabetes educator and mental health counsellor. These health professionals, based at a non-rural site, upskilled existing staff in their respective rural locations to manage women with DIP.[45] All interventions were delivered face-to-face in a clinic or hospital setting.

Two studies reported some form of tailoring in their interventions.[44,45] One did not specify how this occurred, only that the intervention was developed for a low resource setting.[44] Weiderman and Marcuz (1996) described the modification of the "Sweet Success" program,[45] by clinicians specifically for rural sites.[45] Intervention modifications, planned and actual fidelity were not reported by any of the included articles.

Maternal and infant outcomes reported are outlined in Table 3. All studies reported rates of caesarean section, birthweight in grams and gestational age at birth.[43–45] Pre-eclampsia, polyhydramnios, emergency caesarean section, neonatal hypoglycaemia and APGAR score were included as maternal and infant outcomes in two articles.[43,44] Murfet et al.[44] analysed their primary outcomes using adjusted relative risk as pooled adverse maternal outcomes and pooled adverse neonatal outcomes, respectively.

The primary outcomes, results and conclusions are reported in Appendix III (online supplementary material). Secondary outcomes are listed in Appendix IV. The article evaluating a nurse practitioner-led rural model of care concluded that neonatal outcomes improved, without increasing specialist referral load.[44] This was reported as a reduction in the adjusted relative risk of pooled neonatal adverse outcomes, which was 0.76 (95% confidence interval [CI] 0.61–0.94) for all diabetes types and 0.60 for GDM (95% CI 0.48–0.76).[44] Weiderman and Marcuz[45] reported that their smaller-than-expected sample size limited the ability to draw conclusions. However, trends suggested that adequately upskilled rural clinicians were able to provide comprehensive care with no difference in maternal or infant outcomes when compared to the multidisciplinary team model.[45] The article examining antenatal colostrum expression reported no difference in neonatal hypoglycaemia between women who expressed

TABLE 3 Maternal and infant outcomes for women with diabetes in pregnancy in rural areas

		Author, year		
		Murfet et al. (2014)[44]	Casey et al. (2019)[43]	Weiderman and Marcuz (1996)[45]
Maternal outcomes	Maternal hypoglycaemia	✓		
	Loss of consciousness	✓		
	Diabetic ketoacidosis	✓		
	Maternal metabolic complications	✓		
	Threatened abortion requiring sutures	✓		
	Preeclampsia	✓	✓	
	Oligohydramnios/polyhydramnios	✓	✓	
	Premature labour/placenta previa	✓		
	2nd–4th degree tear	✓		
	Emergency caesarean		✓	
	Failure to progress/emergency caesarean	✓	✓	✓
	Postpartum haemorrhage	✓		
	Instrumental delivery		✓	
Infant outcomes	Gestational age at birth	✓	✓	✓
	Preterm delivery	✓		
	Birthweight	✓	✓	✓
	Neonatal hypoglycaemia	✓	✓	
	Neonatal respiratory distress syndrome	✓		
	Neonatal macrosomia	✓		
	Birth injuries	✓		
	Neural tube defect	✓		
	Neonatal congenital abnormality	✓		
	Stillbirth or neonatal death	✓		
	Apgar score		✓	✓
	Other neonatal complications	✓	✓	

and stored colostrum antenatally, with the intention of feeding their infant this after birth, and those who did not (p value 0.89).[43]

Two studies were considered as at serious risk of bias,[44,45] and one was considered at moderate risk[43] using the ROBINS-I tool (Appendix V, online supplementary material).[41]

4 | DISCUSSION

This review highlights a major gap in published research regarding antenatal interventions for women with DIP in rural areas, globally. There were only three studies identified that observed or conducted an antenatal intervention in a rural area for women with DIP and reported maternal and infant outcomes. Two studies were interventions,[44,45] one a pre-post design,[44] and the second a non-randomised controlled trial.[45] The third study was a retrospective cohort study.[43] No randomised controlled trials were identified despite a broad search strategy.

There was variation in maternal and infant outcomes reporting between articles, which were highly dependent on the primary aim of the study. Two of the included studies reported tailoring their interventions to a rural setting.[44,45] Due to the heterogenous nature of these three studies and the variation in reporting, it is difficult to draw any practice-based conclusions regarding delivery of healthcare for women with DIP in rural settings, but it flags that this issue has been neglected to date.

Guidelines issued by national bodies such as the American Diabetes Association and the Australasian Diabetes in Pregnancy Society vary between diabetes types.[14–18] Current GDM management guidelines recommend referral to the diabetes educator and dietitian for education

regarding lifestyle management and blood glucose self-monitoring as the first line of treatment, with medication initiated if glycaemic control remains sub-optimal.[14,16,18] Commencement of pharmacotherapy should be individualised, using metformin or insulin as both are considered safe and effective for use during pregnancy.[14,16,17] Pre-existing DIP requires ongoing lifestyle management from conception, with insulin therapy essential for women with type 1 diabetes and likely required for women with type 2 diabetes.[14,15,17,18] Multidisciplinary team management is recommended, which typically includes a credentialled diabetes educator, dietitian, obstetrician, endocrinologist and midwife or antenatal nurse, and may also include an Aboriginal health worker, lactation consultant and exercise physiologist.[14,16,17,18] The extent to which these guidelines are met in practice is unknown, as demonstrated by the lack of reporting on models of care found by this systematic review.

Current guidelines recommend women with GDM see a dietitian for a minimum of three appointments.[16] The feasibility of translating guidelines such as these to rural areas, where there are fewer allied health and specialists available,[21] is unknown. To plan and implement best practice models of care, details of current practices need to be described and evaluated.[46,47] This should include reporting of specific adaptions for the rural context such as tertiary clinic support, availability of specialist clinical staff and utilisation of telehealth in models. Context-specific solutions can then be implemented to address key issues within rural models of care.

This article is the first, to the best of the authors' knowledge, to report the published interventions on rural healthcare delivery for women with DIP. Although systematic reviews have been conducted previously which centred on outcomes for women with GDM, none have had a rural focus.[48,49] One review article investigated pregnancy outcomes of women and infants in metropolitan and rural areas; however, the type of review was not specified and was limited to pre-pregnancy diabetes in the Australian context.[7] A lack of large Australian studies in rural areas limited the ability of the review to draw conclusions when comparing rural and metropolitan outcomes.[7] A systematic review explored the prevalence of DIP for Aboriginal and Indigenous women globally; however, minimal focus was placed on the level of remoteness of studies.[50] Neither of these reviews reported on the models of care resulting in the specified outcomes.[7,50]

The lack of research targeting rural women with DIP, especially when considering healthcare delivery, reflects the wider gaps in research. There is a well-established gap in healthcare access and health outcomes for rural residents compared to those in metropolitan areas.[21,51] Additionally, it is known that healthcare delivery models must be modified to fit with the challenges of rural settings.[52] The services offered in rural areas are typically at facilities with less infrastructure, and are required to provide a broader range of services to a geographically dispersed population due to reduced access to specialist services.[52] The lack of studies meeting the criteria for this review demonstrates the limited research being undertaken into how models of care can be modified and evaluated in a rural context.

One of the challenges in conducting this review was the lack of international consensus on the definition of *rural*. Similar terms used by various organisations include remote, regional and non-metropolitan.[53] Definitions of rurality has evolved greatly over time to fit with changes in population density and increasing consideration of rural based policy and resource allocation.[53,54] As an example the Modified Monash Model, which is the current Australian measure, is predominantly focussed around the relationship between population size, geographical location and healthcare service access.[55]

Research on GDM management has been conducted in Australia.[56] A model of care based on the Queensland GDM management guidelines was adapted from metropolitan sites and implemented in two regional areas.[56,57] This research focused on the dietetic component of the model of care, aiming to increase adherence to Queensland Health clinical guidelines.[16] These guidelines recommended that women were seen by a dietitian within 1 week of a GDM diagnosis, and had a minimum of three appointments with a dietitian throughout their pregnancy.[16,56] Although this did not meet the inclusion criteria here due to a lack of maternal and infant outcome reporting, it highlighted the disparity between evidence-based practice and the current GDM model of care.[57]

Strengths of the current review include that a comprehensive search strategy across several databases was conducted to reduce the likelihood of missing eligible articles. Also, both intervention and observational studies were included, providing a thorough review of the available evidence. A limitation of this review is that some older studies may have been missed given that only published articles from 1990 onwards were considered. Additionally, the small number and heterogeneity of included articles limited the ability to draw practice-based conclusions on DIP care in rural areas.

Considering nearly one fifth of individuals in high-income countries reside in rural areas,[51] and the established worse health outcomes for rural mothers with DIP and their babies,[24,26] there is a significant lack of research to reflect this population.[28,58] A structured treatment approach has shown to improve outcomes in women with GDM.[12,13,19] However, it is unknown if

these approaches can be translated to a rural setting. More research is required to investigate and evaluate the current models of care in rural areas and their impact on maternal and infant outcomes.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS

Conceptualisation: EP, MR, LB, CC, KW, TS; methodology: EP, MR, TS; data curation: EP, GP; investigation: EP, GP, KR, SH; data analysis: EP; validation: EP, TS; writing: EP, MR, LB, TS; editing: EP, GP, MR, LB, KR, SH, CC, KW, TS; supervision: MR, LB, CC, TS; visualisation: MR, LB, TS; project administration: TS. All authors approved the final version of the manuscript for publication.

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REFERENCES

1. Yuen L, Saeedi P, Riaz M, et al. Projections of the prevalence of hyperglycaemia in pregnancy in 2019 and beyond: results from the International Diabetes Federation Diabetes Atlas, 9th edition. *Diabetes Res Clin Pract*. 2019;157:1-12. doi:10.1016/j.diabres.2019.107841
2. International Diabetes Federation. IDF Diabetes Atlas. 2019. Accessed October 31, 2021. https://www.diabetesatlas.org/upload/resources/material/20200302_133351_IDFATLAS9e-final-web.pdf
3. Diabetes Australia. Position statement: gestational diabetes in Australia. August 2020. Accessed October 31 2021. https://www.diabetesaustralia.com.au/research-advocacy/position-statements/
4. Australian Institute of Health and Welfare. *Diabetes*. AIHW; 2020:1-19.
5. Australian Institute of Health and Welfare. *Diabetes in Pregnancy 2014–2015*. AIHW; 2019:1-24.
6. Koning SH, van Zanden JJ, Hoogenberg K, et al. New diagnostic criteria for gestational diabetes mellitus and their impact on the number of diagnoses and pregnancy outcomes. *Diabetologia*. 2018;61(4):800-809. doi:10.1007/s00125-017-4506-x
7. Williamson R, McCarthy EA, Shub A. Pregnancy outcomes for women with pre-pregnancy diabetes mellitus in Australian populations, rural and metropolitan: a review. *Aust N Z J Obstet Gynaecol*. 2019;59(2):183-194. doi:10.1111/ajo.12913
8. Bellamy L, Casas J-P, Hingorani AD, Williams D. Type 2 diabetes mellitus after gestational diabetes: a systematic review and meta-analysis. *Lancet*. 2009;373(9677):1773-1779. doi:10.1016/S0140-6736(09)60731-5
9. Kim C, Newton KM, Knopp RH. Gestational diabetes and the incidence of type 2 diabetes. *Diabetes Care*. 2002;25(10):1862. doi:10.2337/diacare.25.10.1862
10. Royal Australian College of General Practitioners. *Management of Type 2 Diabetes: A Handbook for General Practice*. RACGP; 2020.
11. Silva CM, Arnegard ME, Maric-Bilkan C. Dysglycemia in pregnancy and maternal/fetal outcomes. *J Womens Health*. 2021;30(2):187-193. doi:10.1089/jwh.2020.8853
12. Crowther CA, Hiller JE, Moss JR, McPhee AJ, Jeffries WS, Robinson JS. Effect of treatment of gestational diabetes mellitus on pregnancy outcomes. *N Engl J Med*. 2005;352(24):2477-2486. doi:10.1056/NEJMoa042973
13. Landon MB, Spong CY, Thom E, et al. A multicenter, randomized trial of treatment for mild gestational diabetes. *N Engl J Med*. 2009;361(14):1339-1348. doi:10.1056/NEJMoa0902430
14. National Collaborating Centre for Women's and Children's Health (UK). *Diabetes in Pregnancy: Management of Diabetes and Its Complications from Preconception to the Postnatal Period*. National Institute for Health and Care Excellence; 2015.
15. Rudland VL, Price SAL, Hughes R, et al. ADIPS 2020 guideline for pre-existing diabetes and pregnancy. *Aust N Z J Obstet Gynaecol*. 2020;60(6):E18-e52. doi:10.1111/ajo.13265
16. Queensland Health. Queensland Clinical Guidelines: Gestational diabetes mellitus (GDM). Guideline No. MN21.33-V5-R26. July 2021. Accessed October 31, 2021. https://www.health.qld.gov.au/qcg
17. Diabetes Canada Clinical Practice Guidelines Expert Committee. Diabetes Canada 2018 clinical practice guidelines for the prevention and management of diabetes in Canada: diabetes in pregnancy. *Can J Diabetes*. 2018;42(Suppl1):S255-S282.
18. American Diabetes Association. Management of diabetes in pregnancy: standards of medical care in diabetes—2021. *Diabetes Care*. 2021;44(Suppl 1):S200-S210. doi:10.2337/dc21-S014
19. Rahmani A, Afandi B. Improving neonatal complications with a structured multidisciplinary approach to gestational diabetes mellitus management. *J Neonatal Perinatal Med*. 2015;8(4):359-362. doi:10.3233/NPM-15915014
20. Maternal SA. Neonatal & Gynaecology Community of practice. South Australian perinatal practice guideline: diabetes mellitus and gestational diabetes. *South Australia: Government of South Australia*. 2019;1-30.
21. Australian Institute of Health and Welfare. *Rural & Remote Health*. AIHW; 2019.
22. Rural Health Information Hub. Rural data explorer. 2019. Accessed October 31, 2021. https://www.ruralhealthinfo.org/data-explorer?id=200
23. Hoang H, Le Q, Terry D. Women's access needs in maternity care in rural Tasmania, Australia: a mixed methods study. *Women Birth*. 2014;27(1):9-14. doi:10.1016/j.wombi.2013.02.001
24. National Advisory Committee on Rural Health and Human Services. *Maternal and Obstetric Care Challenges in Rural America*. Department of Health and Human Services; 2020.
25. Grzybowski S, Fahey J, Lai B, et al. The safety of Canadian rural maternity services: a multi-jurisdictional cohort analysis. *BMC Health Serv Res*. 2015;15(1):410. doi:10.1186/s12913-015-1034-6

26. Grzybowski S, Stoll K, Kornelsen J. Distance matters: a population based study examining access to maternity services for rural women. *BMC Health Serv Res*. 2011;11(1):147. doi:10.1186/1472-6963-11-147
27. Combier E, Charreire H, Le Vaillant M, et al. Perinatal health inequalities and accessibility of maternity services in a rural French region: closing maternity units in Burgundy. *Health Place*. 2013;24:225-233. doi:10.1016/j.healthplace.2013.09.006
28. Barclay L, Phillips A, Lyle D. Rural and remote health research: does the investment match the need? *Aust J Rural Health*. 2018;26(2):74-79. doi:10.1111/ajr.12429
29. Utz B, De Brouwere V. "Why screen if we cannot follow-up and manage?" Challenges for gestational diabetes screening and management in low and lower-middle income countries: results of a cross-sectional survey. *BMC Pregnancy Childbirth*. 2016;16(1):341. doi:10.1186/s12884-016-1143-1
30. Goldenberg RL, McClure EM, Harrison MS, Miodovnik M. Diabetes during pregnancy in low- and middle-income countries. *Am J Perinatol*. 2016;33(13):1227-1235. doi:10.1055/s-0036-1584152
31. Mounier-Jack S, Mayhew SH, Mays N. Integrated care: learning between high-income, and low- and middle-income country health systems. *Health Policy Plan*. 2017;32(suppl_4):iv6-iv12. doi:10.1093/heapol/czx039
32. Edwards L, Connors C, Whitbread C, Brown A, Oats J, Maple-Brown L. Improving health service delivery for women with diabetes in pregnancy in remote Australia: survey of care in the Northern Territory diabetes in pregnancy partnership. *Aust N Z J Obstet Gynaecol*. 2014;54(6):534-540. doi:10.1111/ajo.12246
33. McLean A, Kirkham R, Campbell S, et al. Improving models of care for diabetes in pregnancy: experience of current practice in far North Queensland, Australia. *Front Public Health*. 2019;7(192):1-9. doi:10.3389/fpubh.2019.00192
34. Meloncelli N, Barnett A, de Jersey S. Staff resourcing, guideline implementation and models of care for gestational diabetes mellitus management. *Aust N Z J Obstet Gynaecol*. 2020;60(1):115-122. doi:10.1111/ajo.13032
35. Hirsch IB. History of glucose monitoring. *Role of Continuous Glucose Monitoring in Diabetes Treatment*. American Diabetes Association; 2018:1. https://www.ncbi.nlm.nih.gov/books/NBK538968/
36. Negrato CA, Gomes MB. Historical facts of screening and diagnosing diabetes in pregnancy. *Diabetol Metab Syndr*. 2013;5(1):22. doi:10.1186/1758-5996-5-22
37. The World Bank Group. *World Bank Country and Lending Groups*. The World Bank. Accessed October 31, 2021. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.
38. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. doi:10.1136/bmj.n71
39. Feig DS, Corcoy R, Moller Jensen D, et al. Diabetes in pregnancy outcomes: a systematic review and proposed codification of definitions. *Diabetes Metab Res Rev*. 2015;31(7):680-690. doi:10.1002/dmrr.2640
40. Hoffmann TC, Glasziou PP, Boutron I, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *BMJ*. 2014;348:g1687. doi:10.1136/bmj.g1687
41. Sterne JAC, HernÃ¡n MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomized studies of interventions. *BMJ*. 2016;355:i4919. doi:10.1136/bmj.i4919
42. Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*. 2019;366:14898. doi:10.1136/bmj.l4898
43. Casey JRR, Banks J, Braniff K, Buettner P, Heal C. The effects of expressing antenatal colostrum in women with diabetes in pregnancy: a retrospective cohort study. *Aust N Z J Obstet Gynaecol*. 2019;59(6):811-818. doi:10.1111/ajo.12966
44. Murfet GO, Allen P, Hingston TJ. Maternal and neonatal health outcomes following the implementation of an innovative model of nurse practitioner-led care for diabetes in pregnancy. *J Adv Nurs*. 2014;70(5):1150-1163. doi:10.1111/jan.12277
45. Weiderman WC, Marcuz L. Gestational diabetes: a triage model of care for rural perinatal providers. *Am J Obstet Gynecol*. 1996;174(6):1719-1724. doi:10.1016/s0002-9378(96)70202-8
46. Simmons D, Cheung NW, McIntyre HD, et al. The ADIPS pilot national diabetes in pregnancy audit project. *Aust N Z J Obstet Gynaecol*. 2007;47(3):198-206. doi:10.1111/j.1479-828X.2007.00718.x
47. Sina M, Cade TJ, Flack J, et al. Antenatal models of care for women with gestational diabetes mellitus: vignettes from an international meeting. *Aust N Z J Obstet Gynaecol*. 2020;60:720-728. doi:10.1111/ajo.13144
48. Hillyard M, Casson K, Sinclair M, Murphy M. Can physical activity and dietary interventions improve maternal and fetal outcomes in women with gestational diabetes mellitus? A systematic review and meta-analysis. *Evid Based Midwifery*. 2018;16(3):76-83.
49. Farrar D, Simmonds M, Bryant M, et al. Treatments for gestational diabetes: a systematic review and meta-analysis. *BMJ Open*. 2017;7(6):e015557. doi:10.1136/bmjopen-2016-015557
50. Porter C, Skinner T, Ellis I. The current state of indigenous and aboriginal women with diabetes in pregnancy: a systematic review. *Diabetes Res Clin Pract*. 2012;98(2):209-225. doi:10.1016/j.diabres.2012.07.006
51. The World Bank. *Rural Population (% of Total Population)—High Income*. World Bank Group; 2018. Accessed October 31, 2021. https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=XD
52. Standing Council on Health. *National Strategic Framework for Rural and Remote Health*. Australian Department of Health, Australian Government; 2012. Accessed October 21, 2021. https://www1.health.gov.au/internet/main/publishing.nsf/Content/national-strategic-framework-rural-remote-health
53. Australian Institute of Health and Welfare. *Rural, Regional and Remote Health: A Guide to Remoteness Classifications*. AIHW; 2004. Accessed October 31, 2021. https://www.aihw.gov.au/reports/rural-remote-australians/guide-to-remoteness-classifications/summary
54. Nelson KS, Nguyen TD, Brownstein NA, et al. Definitions, measures, and uses of rurality: a systematic review of the empirical and quantitative literature. *J Rural Stud*. 2021;82:351-365. doi:10.1016/j.jrurstud.2021.01.035
55. Australian Government Department of Health. Modified Monash Model. Australian Commonwealth of Australia; 2020.

Accessed October 31, 2021. https://www.health.gov.au/health-workforce/health-workforce-classifications/modified-monash-model

56. Wilkinson SA, McCray SJ, Kempe A, Sellwood B. Clinically relevant improvements achieved from a facilitated implementation of a gestational diabetes model of care. *Nutr Diet*. 2018; 75(3):271-282. doi:10.1111/1747-0080.12404
57. Wilkinson SA, McCray S, Beckmann M, McIntyre HD. Evaluation of a process of implementation of a gestational diabetes nutrition model of care into practice. *Nutr Diet*. 2016;73(4):329-335. doi:10.1111/1747-0080.12233
58. Alston L, Partridge SR. Limited dietary interventions in rural Australian communities: a systematic review. *Nutr Diet*. 2021; 78(1):57-68. doi:10.1111/1747-0080.12612

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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REVIEW

Efficacy and safety of biophenol-rich nutraceuticals in adults with inflammatory gastrointestinal diseases or irritable bowel syndrome: A systematic literature review and meta-analysis

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Abstract

Aim: Biophenol-rich nutraceuticals may be an adjuvant treatment for Crohn's disease (CD), ulcerative colitis (UC), symptomatic uncomplicated diverticular disease (SUDD), and irritable bowel syndrome (IBS). This systematic review and meta-analysis aimed to determine the efficacy and safety of biophenol-rich nutraceutical supplementation on CD, UC, SUDD, and IBS on gastrointestinal symptoms (GIS), quality of life (QoL), inflammatory and oxidative stress biomarkers, and adverse events compared to usual care or placebo.

Methods: PubMed, Embase, CINAHL, and CENTRAL were searched for randomised controlled trials until 27 April 2020. Outcomes were GIS, inflammatory and oxidative stress markers, QoL, and adverse events. The Cochrane Risk of Bias tool and GRADE were used to appraise studies. Data were pooled using Revman.

Results: Twenty-three trials in CD, UC, and IBS patients were included. Compared with placebo, biophenol-rich nutraceuticals improved GIS (SMD: 0.43 [95%CI: 0.22, 0.63]; GRADE: very low) in UC, CD, and IBS participants. In UC and CD participants, biophenol-rich nutraceuticals improved CRP by 1.6 mg/L [95%CI:0.08, 3.11; GRADE: low], malondialdehyde by 1 mmol/L [95%CI:0.55, 1.38; GRADE: low]; but only resveratrol improved QoL (SMD: −0.84 [95%CI: −1.24, −0.44; GRADE: high). Resveratrol (for UC and CD participants) and peppermint oil (for IBS participants) had greater certainty in the evidence for improving GIS and QoL (GRADE: moderate to high). There was no effect on adverse events ($P > .05$).

Joanna Giang and Xiao Lan contributed to this work equally.

Conclusions: Biophenol-rich nutraceuticals may be an effective and safe adjuvant treatment for the management of CD, UC, and IBS; with higher certainty of evidence for resveratrol for UC and CD and peppermint oil for IBS.

KEYWORDS

Crohn disease, diverticular diseases, inflammatory bowel diseases, irritable bowel syndrome, polyphenols, ulcerative colitis

1 | INTRODUCTION

Inflammatory-related gastrointestinal conditions, such as Crohn's disease (CD), ulcerative colitis (UC), symptomatic uncomplicated diverticular disease (SUDD), and irritable bowel syndrome (IBS), are an emerging global health concern, with incidence and prevalence predicted to increase worldwide.[1-3] Although CD, UC, SUDD, and IBS all have unique pathophysiology, they share gastrointestinal symptoms such as abdominal pain, cramping, bloating, diarrhoea, and/or constipation.[4-6] Inflammation and/or oxidative stress play a role in the pathophysiology of CD, UC, SUDD[7,8]; however, not consistently in IBS.[9] From the patient perspective, burden is often introduced not only by the percieved symptoms, but lifelong financial and personal costs and treatment side effects, leading to reduced quality of life and suffering.[10-12] The rising prevalence of these conditions and subsequent hospitalisations also present a substantial burden to health-care systems.[13]

Current therapies for the treatment and management of inflammation-related gastrointestinal conditions include a variety of medical, diet, and lifestyle recommendations[14-17]; however, biophenols have recently gained interest as a possible adjuvant therapy for a range of conditions.[18-20] Biophenols, sometimes referred to as polyphenols, are phytochemicals found in foods such as extra virgin olive oil, peanuts, turmeric, ginger, tea, and peppermint. Although polyphenols are the more common term for such phytochmicals, they represent only phenolic compounds with two or more aromatic benzene rings.[21] Recently, there has been a move towards utilising the more scientifically accurate term of biophenols, which represent all plant-derived phenols.[21] The benefits of biophenols have been suggested for the treatment of chronic conditions in humans, such as decreasing toxicity in hemodialysis, improving mental health and cognitive performance, managing nausea and vomiting in chemotherapy, or reducing cardiovascular disease risk.[19,22-27]

The beneficial effects of biophenols are due to a variety of mechanisms, including their antioxidant, antiglycation, and anti-inflammatory activities on glucose and lipid metabolism as well as cell proliferation and interactions with the gut microbiota.[28-30] More recently, there is a growing body of interventional research exploring the potential of biophenol-rich nutraceuticals on patient-centered outcomes in gastrointestinal conditions.[31,32] However, the efficacy and safety of biophenol-rich nutraceuticals for such conditions has not been systematically reviewed and certainty in the body of evidence for their adjuvant treatment potential is unknown.

This systematic review and meta-analysis aimed to determine the efficacy and safety of biophenol-rich nutraceutical supplementation on CD, UC, SUDD, and IBS on gastrointestinal symptoms (GIS), quality of life (QoL), inflammatory and oxidative stress biomarkers, and adverse events compared to usual care or placebo.

2 | METHODS

This systematic review was written in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[33] and was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO: 159820).

Relevant studies were identified through a systematic search of the Cochrane Central Library, Medline (via PubMed), Embase (via Ovid), and CINAHL databases for articles published since database inception to 27 April 2020. Controlled vocabulary search terms were used where appropriate to describe major biophenol classes, disease states, and study designs in combination with keywords (Table S1). A snowball search was also conducted, whereby reference lists of included studies and similar reviews were considered to identify additional studies not found in the systematic search strategy, up until 9 December 2019.

Inclusion criteria for participants were human adults aged ≥18 years with CD, UC, SUDD, or IBS. Where age range was not reported, samples were included if the mean age was ≥18 years. Inclusion criteria for types of studies were parallel or crossover randomised controlled trials (RCTs). Studies were included if the intervention group were treated with an orally consumed biophenol-rich nutraceutical with no coadministration of any test

product or therapy beyond standard care for more than 1-week. Biophenol-rich nutraceuticals were included if the test product was listed on the Phenol-Explorer 3.6 database, which is an independent database compiling over 500 biophenols.[34] Studies were included if comparator groups were treated with standard care alone (if this standard care was also provided to the intervention group) or placebo. Studies were included if they were published in languages spoken by the authorship team (English and Chinese). Studies in other languages were included only if they could be translated to English using Google Translate Software.[35] Exclusion criteria for study designs were review or observational studies, studies that did not report associated outcomes, or studies which did not undergo peer review (ie, grey literature, conference papers, abstracts).

Following study deduplication using DeDuplicate,[36] EndNote,[37] and Covidence 2019,[38] the initial title and abstracts screening, then full-text screening of articles, was conducted on Covidence by two investigators independently. Disagreements between reviewers were resolved by consensus or third investigator.

The primary outcome of interest was GIS; and secondary outcomes were inflammatory markers (e.g., C-reactive protein (CRP), calprotectin, interleukin-6 (IL-6), interleukin-8 (IL-8)), oxidative stress markers, QoL, and adverse events. Adverse events were considered any patient-reported side effect related or potentially related to the intervention or control conditions.

Data were extracted from relevant studies using the following parameters: author/date, study design, sample size and attrition, study duration, sample demographics (eg, age, sex, type of gastrointestinal condition), intervention characteristics (type of biophenol, dosing regimen, duration), and outcomes as described above. Extracted continuous outcome data were baseline, follow-up, and change measure of central tendency (mean or median), variation or precision (SD, SE, or 95% confidence intervals (CI)) for both groups as well as *P*-value for change over time and between groups. If mean change was not reported, it was calculated and the SD of the change was estimated using the Review Manager calculator (Versions 5.3 Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012).[39] Extracted categorical outcome data were number of events. Data were extracted by a single investigator and checked for accuracy by a second investigator, as were calculated data.

Internal study quality was assessed using the Cochrane Risk of Bias tool, which included assessing random sequence generation, allocation sequence concealment, blinding, and incomplete outcome data.[40] Risk of bias was assessed independently by two researchers.

Certainty in the body of evidence informing the estimated effect was assessed via the Grading of Recommendation, Assessment, Development and Evaluation (GRADE) assessment tool.[41] Although GRADE may be applied to meta-analysed or narratively synthesised data; due to the large number of potential outcomes included in this study only meta-analysed outcomes were assessed via GRADE. Certainty in the body of evidence was judged by considering risk of bias, inconsistency, indirectness, imprecision, publication bias, effect size, dose-response, and plausible confounding. Considering these factors, each pooled outcome was rated as having high, moderate, low, or very low certainty. The GRADE certainty in the estimated effect sizes was assessed by two investigators independently and judgements were confirmed by a third investigator. Publication bias was assessed via funnel plot.

Outcome data were pooled where adequately reported change data (i.e., difference from baseline to follow-up) was available or could be calculated for two or more interventions using Review Manager (Versions 5.3 Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012).[39] Continuous outcomes were pooled using the inverse variance test and reported as mean difference or standardised mean difference (SMD) if different scales/measurement tools were used. SMD effect sizes of <0.4 were considered small, 0.4 to 0.7 moderate, and >0.7 large.[42] Pooled categorical outcomes were assessed using Mantel-Haenszel test and reported as odds ratios (OR). Heterogeneity was evaluated with the I^2 statistic, where a value >50% was considered to represent substantial statistical heterogeneity.[43] $P < .05$ was considered as statistically significant. Pre-registered sensitivity analyses were undertaken in models with substantial statistical heterogeneity using participant demographics, study quality, differences in measurement tools, intervention factors, or confounding variables. Type of inflammatory-related gastrointestinal condition and type of nutraceutical administered were explored for significant subgroup effects.

3 | RESULTS

The systematic search identified 3008 records and a further four were identified through the snowball search. After deduplication and title/abstract screening, the full text of 93 articles were evaluated for eligibility and 23 were included (Figure S1). Most RCTs had a low to unclear risk of bias and two studies had a high risk of bias (Figure 1; justifications Table S2). There were 10 RCTs included where funding was received from a

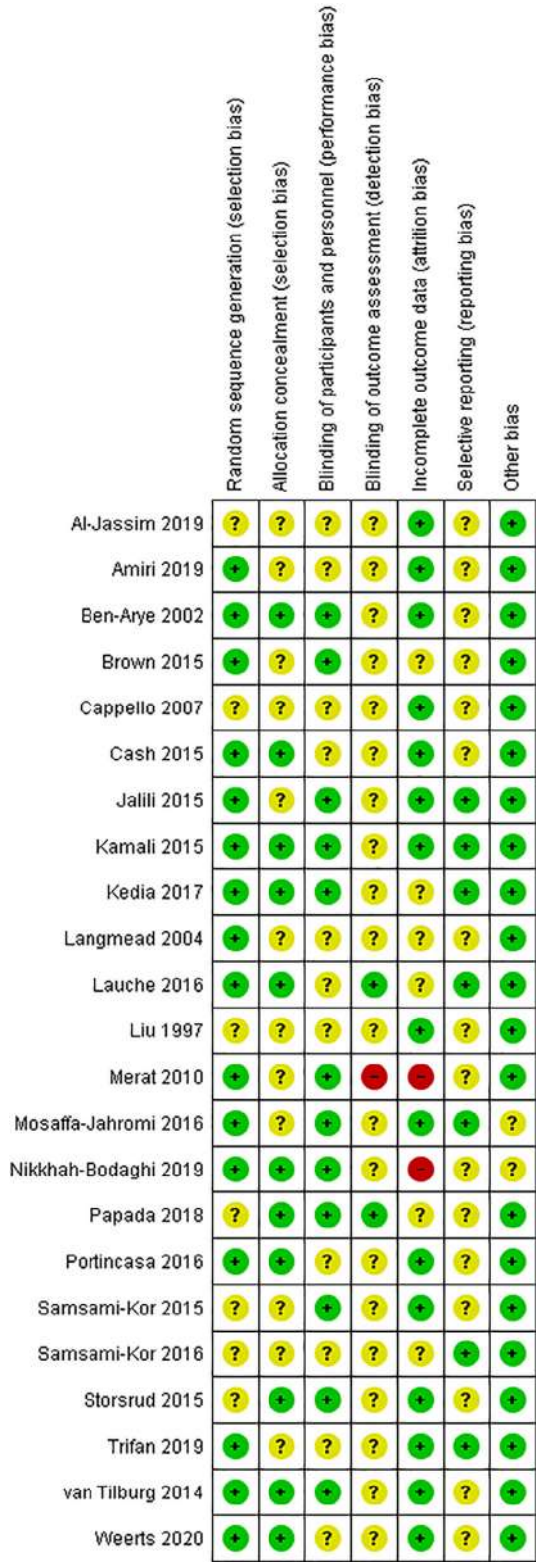

FIGURE 1 Risk of bias summary of randomised controlled trials examining the effect of biophenol-rich nutraceuticals on gastrointestinal symptoms and related outcomes in adults with inflammatory related gastrointestinal conditions

source with a potential interest in a positive result (Tables 1 and 2).

All 23 included RCTs were placebo-controlled; 21 were parallel and two were cross-over (Tables 1 and 2). Two parallel RCTs in participants with IBS had two intervention groups; therefore, a total of 25 interventions arms were included. Most of the studies were from Iran (n = 10 RCTs), followed by the United States (n = 2 RCTs), and Italy (n = 2 RCTs). All other RCTs were from different countries across Europe, the Middle East, and Asia.

Total study sample sizes ranged from n = 16[58] to n = 189[63] (N = 1566 total participants; Tables 1 and 2). Of the 25 interventions, 16 (64%) recruited participants with active IBS (Table 2), seven (28%) with mild to moderate UC, and two (8%) with inflammatory bowel disease (IBD; i.e., UC or CD) (Table 1). No included RCT recruited participants with SUDD.

Peppermint oil was the most studied intervention (n = 5 RCTs in IBS participants), followed by ginger (*Zingiber officinale*) (n = 2 RCTs in IBS participants, n = 1 RCT in IBD participants), resveratrol (n = 2 RCTs in IBD participants), and *aloe vera* (n = 1 RCT in IBS participants, n = 1 RCT in IBD participants). Four RCTs, all in IBS participants, used an intervention product composed of mixed biophenols (a blend of two to four biophenols in powder or capsule form). Other interventions were reported by a single study (curcumin, wheat grass, anise oil, soy isoflavones, mastic tree (*Pistacia lentiscus*), yarrow (Achillea wilhelmsii C. Koch), pomegranate peel; Tables 1 and 2). Study durations ranged from 2 to 12 weeks. The most common mode of nutraceutical delivery was capsule form (n = 17 RCTs, 74%). Other modes of delivery included tablet (n = 2 studies), drink (n = 2 studies), syrup (n = 1 study), and gel form (n = 1 study). Of the four studies that reported compliance, adherence to the prescribed supplements ranged from 67%[64] to 100%[50,51,56] with no difference between intervention and control groups ($P > .05$).

Gastrointestinal symptom scores were measured using condition-specific tools including visual analogue scales (VAS), Irritable Bowel Syndrome Symptom Scoring Scale, the Simple Clinical Colitis Activity Index, the Disease Activity Index, Lichtiger Colitis Activity Index, Partial Mayo Score, and Harvey-Bradshaw Index (Table 2). Twenty-three intervention groups assessing GIS that were able to be pooled with meta-analysis used yarrow, *aloe vera*, curcumin, mastic tree, pomegranate peel, resveratrol, ginger, anise oil, peppermint oil, soy isoflavones, or mixed biophenols.

Meta-analysis found that compared with placebo, biophenol-rich nutraceuticals significantly improved GIS with a moderate effect size (SMD: 0.43 [95%CI: 0.22, 0.63], $P < .0001$, I^2: 64%, GRADE: very low; Table S3, n = 18 studies, n = 21 intervention groups, n = 1187 participants; Figure 2). Sensitivity analysis did not

TABLE 1 Characteristics and findings of n = 9 included randomised controlled trials which examined orally consumed biophenol-rich nutraceuticals in participants with inflammatory bowel disease

Characteristics	Intervention	Comparator	Outcomes[a]
Yarrow (Achillea wilhelmsii C. Koch)[44]			
DBPCRCT, 2-arms, parallel: Iran, N 49 (IG: n = 23, CG: n = 26), n = 9 (18%) attrition. Mild-to-moderate active UC: 53% F, μ34.5 y (range 19-55 y). Funding and COI not described.	n = 20 at FU. Type: Capsule with 0.124 mg/g powdered caffeic acid extract from fresh aerial parts of *A. Wilhelmsii C.* Koch. Dose: 2 capsules/day (1 capsule BDS). Duration: 1 month.	n = 20 at FU. Type: Placebo capsule with hydroxypropyl methylcellulose powder. Dose: 2 capsules/day (1 capsule BDS). Duration: 1 month.	Adverse events: IG: n = 1/23. CG: 0/26. GIS—Partial Mayo Score (score[b]): IG: baseline 5.35 ± 1.69, FU 2.45 ± 2.16, change −2.9 ± 0.46, $P < .001$. CG: baseline 5 ± 1.94, FU 2.65 ± 1.89, change −2.35 ± 0.46, $P < .001$. Inflammatory marker—CRP (mg/L): IG: baseline 5.4 ± 0.3, FU 2.6 ± 1.4, change −2.8 ± 5.88, $P = .04$. CG: baseline 0.5 ± 0.1, FU 0.65 ± 0.35, change 0.15 ± 5.88, $P = .91$. $P = .12$ between groups.
Aloe vera[45]			
DBPCRCT, 2-arms, parallel: United Kingdom, N = 44 (IG: n = 30, CG: n = 14), n:9 (20%) attrition. Mild-to-moderately active UC: 50%F, IG μ40 y (22-76 y), CG μ36 y (20-55 y). Independently funded. No COI declared.	n = 30 at FU. Type: *Aloe Vera* gel (>95% of active ingredient—active ingredient not specified). Dose: 100 mL BDS, Starting with 25 to 50 mL BDS. Duration: 4 weeks	n = 14 at FU. Type: Liquid placebo containing flavorings, no known active agents, matched for taste and appearance. Dose: Starting with 25 to 50 mL BDS. Duration: 4 weeks.	Adverse effects: IG: n = 6/30, CG: CG: 4/14. GIS—SCCAI (score[b]): IG: baseline median 6.5 (IQR: 5.2-8.2), FU median 6.0 (IQR: 2.0-9.0), change −0.5 ± 5.2, $P = .01$. CG: baseline 6.1 (4.7-7.6), FU median 4.9 (IQR: 3.3-7.5), change −1.2 ± 3.1 $P = .33$. Inflammatory marker—CRP (mg/L): IG: baseline median 5 (IQR: 4-11), FU median 4 (IQR 4-9), change −1 ± 4.4, $P = .33$. CG: baseline median 5 (IQR: 4-8), FU median 4 (IQR: 3-9), change −1 ± 3.7, $P = .22$. $P > .05$ between groups. Quality of life—IBDQ (score[c]): IG: baseline median 4.4 (IQR: 3.2-5.0), FU median 4.8 (3.8-5.7), change 0.4 ± 1.4, $P > .05$. CG: baseline median 4.6 (IQR: 3.6-5.1), FU median 5.8 (IQR: 4.8-5.9), change 1.2 ± 0.8, $P < .05$).
Curcumin[46]			
DBPCRCT, 2-arms, parallel: India, N = 62 (IG: n = 29, CG: n = 33), n = 21 (34%) attrition. Mild-to-moderate UC: 34%F, IG μ36 ± 12 y, CG: μ34 ± 7 y. Independently funded, no COI declared.	n = 16 at FU. Type: Curcumin and mesalamine. Dose: 2.4 g/d (1 capsule TDS; each capsule 150 mg curcumin). Duration: 8 weeks	n = 25 at FU. Type: Placebo and mesalamine. Dose: 2.4 g/d (1 capsule TDS). Duration: 8 weeks	Adverse events: IG: 0/16, CG: 1/25. GIS—DAI (score[b]): IG: baseline 5.2 ± 2.0, FU 3.4 ± 3.1, change −1.8 ± 0.76, $P = .711$. CG: baseline 5.5 ± 1.9, FU 3.8 ± 2.8, change −1.7 ± 0.76, $P = .711$.

TABLE 1 (Continued)

Characteristics	Intervention	Comparator	Outcomes[a]
Mastic tree (*Pistacia lentiscus*)[47,48]			
DBPCRCT, 2-arms, parallel: Greece, N = 60 (IG = 33, CG = 27), n = 14 (23.3%) attrition. CD and UC: %F NR, 18-67 y. Funding associated with test product; no COI declared.	n = 26 at FU (ITT used) Type: Natural mastiha tablets. Dose: 2.8 g/d (700 mg tablet QDS). Duration: 12 weeks.	n = 20 at FU (ITT used). Type: Placebo capsule. Dose: NR QDS. Duration: 12 weeks.	GIS—HBI (score[b]): IG: baseline 7.8 ± 2.3, FU: 4.7 ± 3.8, change −3.1±4.1, $P < .001$. CG: baseline 6.1 ± 1.8, FU: 4.7 ± 2.6, change −1.4 ± 2.6, $P = .055$. $P = .0635$ between groups. GIS—Partial Mayo Score[b]: IG: baseline 2.8 ± 1.8, FU: 2.0 ± 1.3, change −0.9 ± 2.0, $P = .481$. CG: baseline 3.2 ± 2.0, FU: 2.2 ± 1.6, change −1.0 ± 2.1, $P = .055$. $P = .324$ between groups. Inflammatory marker—calprotectin (ug/g): IG: baseline 1688.6 ± 1712.4, FU: 2744 ± 4910.6, change 1055.4 ± 5043.1, $P = .289$. CG: 2170.6 ± 444.4, FU: 3598.5 ± 3620.4, change 1427.9 ± 5606.1, $P = .029$. $P = .348$ between groups. Inflammatory marker—IL6 (pg/mL): IG: baseline 11.5 ± 12.3, FU: 15.7 ± 13.3, change 4.2 ± 9.7, $P = .021$. CG: baseline 14.4 ± 16.8, FU: 24.3 ± 43.8, change 9.9 ± 33.6, $P = .030$. $P = .955$ between groups. Inflammatory marker—IL10 (pg/mL): IG: baseline 3.1 ± 2.7, FU: 3.1 ± 2.7, change 0.0 ± 3.6, $P = .951$. CG: baseline 8.8 ± 18.9, FU: 9.5 ± 20.1, change 0.6 ± 3.4, $P = .454$. $P = .607$ between groups. Inflammatory marker—CRP (mg/L): IG: baseline 6.8 ± 8.2, FU: 5.7 ± 5.9, $P = .94$, change −1.2 ± 8.3, $P = .41$. CF: baseline 6.4 ± 7.6, FU: 5.3 ± 4.8, $P = .76$, change −1.1 ± 8, $P = .48$. $P = .79$ between groups. Oxidative stress marker—oxLDL (U/l): IG: baseline 160.42 ± 34.26, FU: 140.12 ± 41.91, change −20.3 ± 51.7, $P = .031$. CG: baseline 135.3 ± 48.38. FU: 135.45 ± 38.92, change 0.15 ± 52.76, $P > .05$. $P > .05$ between groups. Quality of life—IBDQ (score[c]): IG: baseline 145.2 ± 27.3, FU: 163.4 ± 30.6, change −18.3 ± 26.4, $P = .0004$. CG: baseline 144.9 ± 27.3, FU: 155.1 ± 33.3, change −10.2 ± 43.6, $P = .23$. $P > .0.5$ between groups.

(Continues)

TABLE 1 (Continued)

Characteristics	Intervention	Comparator	Outcomes[a]
Pomegranate peel[49]			
DBPCRCT, 2-arms, parallel: Iran, N = 78 (IG: n = 39, CG: n = 39), n = 16 (21%) attrition. UC: 45%F, IG: μ41.7 y, CG: μ37.8 y. Independently funded. No COI declared.	n = 29 at FU. Type: Aqueous extract of the *P. granatum* peel. Dose: 8 mL syrup (6 g dry peel)/days (4 mL BDS). Duration: 4 weeks.	n = 33 at FU. Type: Placebo syrup: USP simple syrup formula + approved additives (Amaranth). Matched for appearance and smell. Dose: 8 mL of the placebo syrup (4 mL BDS). Duration: 4 weeks.	Adverse events: Urticaria: IG: n = 2/29, CG: n = 2/33. Nausea: IG: n = 2/29, CG: n = 1/33. Increased appetite: IG: n = 2/29, CG: n = 3/33. $P > .05$ between groups. GIS—LCAI (score[b]): IG: baseline 6.34 ± 1.98, FU: 4.68 ± 3.48, change −1.68 ± 3.85, $P = .019$. CG: baseline 5.57 ± 1.75, FU 4.18 ± 2.62, change −1.39 ± 2.41, $P = .002$.
Resveratrol[50]			
DBPCRCT, 2-arms, parallel: Iran, N = 56 (IG: n = 28, CG: n = 28), n = 3 (5%) attrition. Mild-to-moderate active UC: %F NR, IG: μ37.43 ± 16.54 y, CG: μ38.78 ± 11.65y. Independently funded. No COI declared.	n = 27 at FU (ITT). Type: Resveratrol supplements. Dose: 500 mg trans-resveratrol, 1 capsule daily. Duration: 6 weeks.	n = 26 at FU (ITT). Type: Placebo capsule (medium chain triglycerides), 1 daily. Duration: 6 weeks.	Adverse events: IG: n = 0/28, CG: n = 0/28. GIS—SCCAI (score[b]): IG: baseline 11.67 ± 2.72, FU: 8.14 ± 2.1, change −3.53 ± 1.81, $P < .001$. CG: baseline 10.88 ± 2.69, FU: 9.34 ± 2.65, −1.54 ± 1.81, $P < .001$. Oxidative stress marker—MDA (mmol): IG: baseline 5.62 ± 1.18, FU: 3.42 ± 1.01, change −2.2 ± 4.16, $P = .0094$. CG: baseline 5.26 ± 1.15, FU: 6.93 ± 1.12; change 1.67 ± 4.16, $P = .0430$. Oxidative stress marker—SOD (U/mL): IG: baseline 122.28 ± 11.55, FU 125.77 ± 10.97, change 3.49, $P < .01$. CG: baseline 120.94 ± 16.13, FU 113.47 ± 114.85, change −7.47, $P < .01$. $P = .01$ between groups. Oxidative stress marker—TAC (U/mL): IG: baseline 9.87 ± 1.51, FU: 11.97 ± 1.61, change −2.1 ± 2.9, $P = .0007$. CG: baseline 10.02 ± 2.02, FU 9.41 ± 1.82,change 0.61 ± 2.9, $P = .2755$. $P < .001$ between groups. Quality of life—IBDQ-9 (score[c]): IG: baseline 34.85 ± 7.67, FU: 47.64 ± 8.59, change 12.79 ± 8.74, $P < .01$. CG: baseline 35.67 ± 9.89, FU: 41.08 ± 8.59, change 5.41 ± 8.74, $P < .01$.
Resveratrol[51]			
DBPCRCT, 2-arms, parallel: Iran, N = 50 (IG: n = 25, CG: n = 25), n = 1 (2%) attrition. Mild to moderate active UC: %F NR, IG μ38 y, CG μ39 y. Funding and COI not described.	n = 25 at FU. Type: Resveratrol capsule. Dose: 500 mg/d/capsule, 1 daily. Duration: 6 weeks.	n = 24 at FU. Type: Placebo capsule (medium-chain triglyceride) Dose: NR, 1 daily. Duration: 6 weeks.	GIS—SCCAI (score[b]): IG: baseline 12.34 ± 2.51, FU: 8.41 ± 2.1, change −3.93 ± 2.23, $P < .001$. CG: baseline 10.76 ± 2.55, FU: 9.34 ± 2.65, change −1.42 ± 2.23, $P < .001$. $P < .001$ between groups. Inflammatory marker—CRP (ng/ml): IG: baseline 4764.25 ± 2260.48, FU: 2584.50 ± 1792.80, change −2179.75. CG: baseline 3158.67 ± 2419.55, CU

TABLE 1 (Continued)

Characteristics	Intervention	Comparator	Outcomes[a]
			3538.42 ± 2348.93, change 389.75. P < .001 between groups. Inflammatory marker—TNF-α (pg/mL): IG: baseline 19.70 ± 12.80, FU: 17.20 ± 10.09, change −2.5, *P* < .01. CG: 20.53 ± 13.34, FU: 23.59 ± 14.82, change 3.06, *P* < .01. *P*≤ .001 between groups. Quality of life—IBDQ-9 (score[c]): IG: baseline 32.72 ± 7.52, FU: 47.64 ± 8.59, change 14.92 ± 10.9, *P* < .01. CG: baseline 35.54 ± 9.50, FU: 41.08 ± 8.59, change 5.54 ± 10.91, *P* < .01. *P* < .001 between groups.
Wheat grass[52]			
DBPCRCT, 2-arms, parallel: Israel, N = 24 (IG: n = 12, CG: n = 12)m n = 3 (12%) attrition. Active UC, involving left colon: 33%F, µ35 y. Funding and COI not described.	n = 10 at FU. Type: 100 mL unstandardised fresh wheat grass juice. Dose: Increased from 20 mL/d, optimal dose 100 mL/d by d 5. Duration: 4 weeks.	n = 11 at FU. Type: Placebo juice. Dose: Increased from 20 mL/d, optimal dose 100 mL/d by d 5. Duration: 4 weeks.	Adverse events: IG: n = 7/10, CG: n = 0/11.
Ginger (*Zingiber officinale*)[53]			
DBPCRCT, 2-arms, parallel: Iran, N = 64 (IG: n = 32, CG: n = 32), n = 18 (28.1%) attrition. CD and UC: 35%F, IG: µ41.4 y, CG: µ39.2 y. Independently funded. No COI reported.	n = 24 at FU. Type: Fried ginger powder capsule. Dose: 2000 mg/d (500 mg/capsule QID). Duration: 12 weeks.	n = 24 at FU. Type: Placebo (maltodextrin powder) capsule. Dose: 2000 mg/d (500 mg/capsule QID). Duration: 12 weeks.	GIS—SCCAI (score[b]): IG: baseline 7.6 ±4.03, FU 4.05 ± 1.23, change −3.55 ± 3.56, *P* = .438. CG: baseline 6.2 ± 3.22, FU 5.55 ± 2.39, change −0.65 ± 3.56, *P* = .194. *P* = .017 between groups. Oxidative stress marker—MDA (mmol): IG: baseline 8.33 ± 1.82, FU: 3.87 ± 1.95, change −4.46 ± 2.84, *P* = .016. CG: baseline 7.88 ± 2.24, FU 6.38 ±2.42, change −1.5 ± 2.84, *P* = .000. *P* < .001 between groups. Oxidative stress marker –TAC (U/mL): IG: baseline 1.9 ± 1.2, FU: 2.16 ± 1.16, −0.26 ± 0.58, *P* = .04. CG: baseline 1.99 ± 1.33, FU: 2.17 ± 1.17, change −0.18 ± 0.58, *P* = .14. *P* = 0.64 between groups. Quality of life: IBDQ (score[c]): IG: baseline 44.22 ± 9.79, FU 47.23 ± 9.24, change 3.01 ± 9.6, *P* = .039. CG: baseline 43.12 ± 6, FU 41.87, change −1.25 ± 9.6, *P* = .636. *P* = .140 between groups.

Abbreviations: BDS, twice daily; CD, Crohn's disease; CG, control group; COI, conflict of interest; CRP, c-reactive protein; DAI, disease activity index; d, day; DBPCRCT, double blind placebo controlled randomised controlled trial; F, female; FU, follow-up; GIS, gastrointestinal symptoms; HBI, Harvey-Bradshaw Index; IBDQ, inflammatory bowel disease questionnaire; IG, intervention group; IQR, interquartile range; ITT, intention to treat; LCAI, Lichtiger colitis activity index; MDA, malondialdehyde; NR, not reported; QDS, four times daily; SCCAI, Simple Clinical Colitis Activity Index; SOD, superoxide dismutase; TAC, total antioxidant capacity; TDS, thrice daily; TNF-α, tumour necrosis factor alpha; UC, ulcerative colitis; y, years.

[a]Continuous outcome data reported as mean (µ) ± SD and categorical outcome data reported as number of events/number of participants, unless otherwise specified.

[b]Higher score indicates worse symptoms/activity.

[c]Higher score indicates better symptoms.

TABLE 2 Characteristics and findings of n = 14 included randomised controlled trials which examined orally consumed biophenol-rich nutraceuticals in participants with irritable bowel syndrome

Characteristics	Intervention	Comparator	Outcomes[a]
Aloe vera[54]			
DBPCRCT, 2-arms, parallel: Sweden, N = 68 (IG = 33, CG = 35), 7.4% attrition. IBS: 75%F, IG: μ43.9 y, μ44.2 y. No funding or COI reported.	n = 32 at FU. Type: 250 mg *Aloe barbadensis* Mill. Extract (AVH200), 60 mg ascorbic acid dissolvable tablet. Dose: 500 mg/d (250 mg BD). Duration: 4-weeks.	n = 31 at FU. Type: 60 mg ascorbic acid and excipients dissolvable table. Dose: 120 mg/d (60 mg BD). Duration: 4-weeks.	GIS—IBS-SSS (score[b]): IG: baseline 315 ± 83, FU: 257 ± 107, change −58 ± 1.1.9, P = .003. CG: baseline 276 ± 88, FU: 253 ± 100, change −23 ± 69.0, P > .05. P = .03 between groups.
Anise oil[55]			
DBPCRCT, 3-arms [2 eligible], parallel: Iran, N = 80 (IG = 40, CG = 40), 6.25% attrition. IBS: 48.8%, IG μ34.15 y, CG μ32.35 y. No funding or COI declared.	n = 38 at FU. Type: Enteric coated anise oil capsule. Dose: 600 mg/d (200 mg TDS). Duration: 4 weeks.	n = 37 at FU. Type: Enteric coated placebo capsule. Dose: NR. Duration: 4 weeks.	Adverse event: IG: n = 0/38. CG n = 0/37. GIS—Abdominal discomfort VAS (score[b]) IG: baseline 5.97 ± 2.35, FU 1.82 ± 1.43, change −4.15 ± 4.8. CG: baseline 5.27 ± 2.12, FU 3.33±1.74, change −1.94 ± 2.7. *P* < .0001 between groups. Quality of life—IBS-QOL (score[c]): IG: baseline 86.20 ± 27.13, FU 64.38±23.10, change −21.8. CG baseline 83.30 ± 21.64, FU 72.82±18.20, change −10.5. *P* < .0001 between groups.
Mixed biophenols[56]			
DBPCRCT, 2-arms, cross-over, no washout: Romania, N = 60 (IG: n = 30, CG: n = 30), 0% attrition. IBS-D: 73%F, μ35 y. No funding or COI declared.	n = 30 at FU. Type: Gelsectan capsule (containing xyloglucan, pea protein and tannins from grape seed extract, and xylo-oligosaccharides) Dose: not clear, 1 capsule BD. Duration: 28 days.	n = 30 at FU. Type: Placebo capsule (not clear). Dose: not clear, 1 capsule BD. Duration: 28 days.	Adverse events: IG: n = 0/30, CG: n = 0/30. GIS—incidence normal stools: IG baseline 1/60, FU 54/60, *P* = .0019. CG baseline 26/60, FU 7/60, *P* = .0001. On day 28, the proportion of patients with normal stools, GIS—IBS-D incidence abdominal pain: IG baseline 38/60, FU: 0/60, *P* = .002. CG 25/60, FU 27/60, *P* = .027. GIS—IBS incidence bloating: IG baseline 38/60, FU 1/60, *P* = .028. CG baseline 25/60, FU 27/60, *P* = .041. Quality of life—IBS-QOL and EQ-5D-3L: data represented graphically only.
Mixed biophenols[57]			
DBPCRCT, 2-arms, cross-over, 1-week washout: Germany, N = 30 (IG: n = 15, CG: n = 15), n = 11 (34%) attrition. IBS-D: 59%F, μ50.3 ± 11.9 y. No funding or COI declared.	n = 20 in the second phase; n = 5 in the third phase. Type: Ayurvedic herbal compound preparation made from curry (*Murraya Koenigii*), pomegranate (*Punica granatum*) and turmeric	n = 6 in the second phase. n = 17 in the third phase. Type: Placebo (hay Graminis flores dep. and Maidis stigmata). Dose: 140 g. Duration: 4 weeks.	Adverse events: IG: n = 9/15. CG: n = 4/15. GIS—IBS-SSS (score[b]): IG: baseline 217.4 ± 91.4, FU: 220.3 ± 90.0, change 2.9 ± 33.64, *P* = .74. CG: baseline

TABLE 2 (Continued)

Characteristics	Intervention	Comparator	Outcomes[a]
	(*Curcuma longa*) in a 6:3:1 ratio. Dose: 10 g (5 g of powder dissolved in 100 mL of warm water BD). Duration: 4 weeks.		226.0 ± 81.8, FU 215.0 ± 89.9, change −11 ± 33.64, $P = .23$. No significant differences between the IG and CG phases. Quality of life—IBS-QOL (score[c]): IG: baseline 69.9 ± 21.6, FU: 72.1 ± 19.0, 2.2 ± 65.83, P = .89. CG: baseline 68.2 ± 19.1 CG: FU 67.4 ± 22.3, change −0.8 ± 65.83, $P = .96$. $P > .05$ between groups.
Mixed biophenols[58]			
DBPCRCT, 2-arms, parallel: United States, N: 16 (IG: n = 8, CG: n = 8), n = 3 (19%) attrition. IBS-C: 81%F, µ38 y (23-57 y). Funding and authors affiliated with test product.	n = 7 at FU. Type: blended extracts in capsule (Quebracho, Conker tree, M. balsamea Willd, peppermint oil). Dose: Quebracho 150 mg (80-82% polyphenol content), Conker tree—470 mg (20% saponin content), M. balsamea Willd oil—0.2 mL; pure peppermint oil (content quantity not specified). Duration: 2 weeks.	n = 6 at FU. Type: Placebo capsule. Dose: NR. Duration: 2 weeks.	Adverse events: IG: n = 0/8, CG: n = 0/8. GIS—Constipation and bloating (score[c]): IG: change 2.62±0.886, $P < .001$. CG: change 0.28 ± 0.39, $P = .141$.
Mixed biophenols[59]			
DBPCRCT, 2-arms, parallel: Italy, N = 21 (IG n = 60, CG n = 61), 4.1% attrition. IBS: 63.6%F, IG µ41.4 y, CG µ39.4 y. Funding associated with test product. No COI declared.	n = 58 at FU. Type: blended essential oils (curcumin and fennel) capsule. Dose: 84 mg/d curcumin and 50 mg fennel essential oil (42 mg curcumin and 25 mg fennel essential oil/capsule BD). Duration: 4 weeks.	n = 58 at FU. Type: Placebo capsule. Dose: not clear BD. Duration: 4 weeks.	Adverse events: IG: 1.7%. CG 3.4%. GIS—IBS-SSS (score[b]): IG: baseline 255.7 ± 39.9, FU: 127.8 ± 77.4, change −127.9 ± 119.89. CG: baseline 263.2 ± 34.3, FU: 195.5 ± 88.0, change −67.7 ± 119.89. $P < .001$. $P < .05$ between groups. Quality of life—IBS-QOL (score[c]): IG: change 17.4 ± 19.2. CG: change 7.7 ± 18.0, P = .003.
Peppermint oil[60]			
DBPCRCT, 2-arms, parallel: Italy, N = 57 (IG: n = 28, CG: n = 29), n = 7 (12%) attrition. IBS: 76%F, µ41 y (20–60). No funding or COI declared.	n = 24 at FU. Type: Enteric-coated, gastro-protected peppermint oil capsules. Dose: 550 mg (225 mg peppermint oil +45 mg of Natrasorb BD). Duration: 4 weeks.	n = 26 at FU. Type: Placebo capsules. Dose: 55 mg maltodextrin (225 mg of maltodextrin with mint flavour BD). Duration: 4 weeks.	Adverse events: IG: n = 1/24. CG: n = 0/26. GIS—incidence ≥50% reduction of total IBS symptoms score: IG: n = 18/24, $P < .01$. CG: n = 10/26, $P < .05$. $P < .05$ between groups.
Peppermint oil[61]			
DBPCRCT, 2-arms, parallel: United States, N = 72 (IG:	n = 34 at FU. Type: Peppermint oil capsules. Dose: 540 mg (180 mg TDS).	n = 36 at FU. Type: Placebo capsules. Dose: NR TDS.	Adverse events: IG: n = 2/34, CG: n = 4/36.

(Continues)

TABLE 2 (Continued)

Characteristics	Intervention	Comparator	Outcomes[a]
n = 35, CG: n = 37), n = 2 (2.7%) attrition. IBS-M and IBS-D: 75%F, IG μ40.2 y, CG μ41 y. Independently funded. COI declared.	Duration: 4 weeks.	Duration: 4 weeks.	GIS—TISS (score[b]): IG: change −1.16 ± 0.897, $P = .0246$. CG: change −0.70 ± 0.737. GIS—incidence of severe symptoms: IG change −66.8%. CG: change −24.9%. $P = .0282$ between groups.
Peppermint oil[62]			
DBPCRCT, 2-arms, parallel: China, N = 110 (IG: n = 55, CG: n = 55), n = 9 (8.1%) attrition. IBS: 40%F, 18-70 y. Funding and COI were not described.	n = 52 at FU. Type: Enteric coated peppermint oil capsule Dose: 561-748 mg/d (187 mg/capsule x 3-4/d) Duration: 4-weeks.	n = 49 at FU. Type: Placebo capsule Dose: 3-4/d, dose not reported. Duration: 4-weeks.	GIS—Incidence abdominal pain: IG: n = 41/51(79%) participants improved. CG: n = 21/49(43%) participants improved. Significant difference between groups ($P < .05$).
Peppermint oil[63]			
DBPCRCT, 3-arms, parallel: Netherlands, N = 189 (unclear number of patients in each group), 5.8% attrition. IBS: 78%F, μ34.4 y. No funding or COI declared.	IG 1: n = 62 at FU. Type: Peppermint oil capsule. Dose:182 mg/d (60.3 mg TDS). Duration: 8-weeks. IG 2: n = 62 at FU. Type: Peppermint oil capsule. Dose:182 mg/d (60.3 mg TDS). Duration: 8 weeks.	n = 64 at FU. Type: Placebo capsule. Dose: Not reported. Duration: 8 weeks.	Adverse events incidence: IG1 4.26 ±0.37. IG2 4.54± 0.45. CG 2.78 ±0.34. GIS—IBS-SSS (score[b]): IG1: baseline 284.52±95.28, FU 192.99±121.65, change −91.53±66.28, $P = .00$. IG2 baseline 285.42±92.47, FU 201.05±120.17, change −84.37±63.34 $P = .00$. CG baseline 276.53±93.44, FU 226.80±119.76, change −49.73 ± 66.28, $P = .00$. $P = .020$ between IG1 and CG. $P = .22$ between IG2 and CG. Quality of life—IBS QOL (score[c]): IG1: baseline 68.8 ± 2.6, FU: 75.9 ± 2.6, change 7.1, $P = .066$. IG2: baseline 69.8 ± 2.5, FU 75.5 ± 2.5, change 5.7, $P = .374$. CG baseline 70.5 ± 2.5, FU 75.0 ± 2.5.
Peppermint oil[64]			
DBPCRCT, 2-arms, parallel: Iran, N = 0 (IG = 45, CG = 45), 33.3% attrition. IBS: 75%F, μ36 y. Independently funded. COI not described.	n = 33 at FU. Type: Peppermint oil capsule Dose: 546 mg/d (182 mg TDS). Duration: 8 weeks.	n = 27 at FU. Type: Placebo capsule. Dose: NR TDS. Duration: 8 weeks.	Adverse events: IG: n = 19/33. CG n = 14/27. GIS—incidence abdominal pain free: IG: baseline n = 0/33, FU n = 14/33. CG: baseline n = 0/27, FU n = 6/2. $P < .001$ between groups. Quality of life—SF-36 (score[c]): IG baseline 57.8 ± 29.3, FU: 63.0 ± 28.2. CG baseline 48.9 ± 29.8, FU: 53.7 ± 26.4. $P = .194$ between groups.
Soy isoflavones[65]			
DBPCRCT, 2-arms, parallel: Iran,	n = 22 at FU. Type: Soy isoflavones capsule	n = 23 at FU.	Adverse events: IG: n = 0/22. CG: n = 0/23.

TABLE 2 (Continued)

Characteristics	Intervention	Comparator	Outcomes[a]
N = 67 (IG: n = 35, CG: n = 32), n = 22 (33%) attrition. IBS: 72%F, IG: μ45.5 y, CG: 40.0 y. Independently funded. No COI declared.	Dose: 40 mg of isoflavones (10 mg of diadzein, 8.5 mg genistein, 1.5 mg glycetin BD). Duration: 6 weeks.	Type: Placebo capsule (corn starch). Dose: 1 capsule BD. Duration: 6 weeks.	GIS—IBS-SSS (score[b]): IG: baseline 23.64 ± 8.17, FU: 12.77 ± 8.16, change −10.87 ± 7.85, $P = .00$. CG: baseline 24.78 ± 11.82, FU: 19.74 ± 12.08, change −5.04 ± 7.85, $P = .00$. No difference between groups $P = .068$. Quality of life—IBS-QOL (score[c]): IG: baseline 64.41 ± 27.78, FU 41.68 ± 28.47, change −22.73 ± 228.31, $P = .65$. CG: baseline 46.70 ± 31.37, FU: 44.17 ± 33.47, change −2.53 ± 228.31, $P = .96$. $P = .009$ between groups.
Ginger (Zingiber officinale)[66]			
DBPCRCT, 3-arms, parallel: Iran, N = 50 (IG = 25, CG = 25), 2% attrition. IBS: age and sex NR. Funding and COI NR.	IG1: n = 15 at FU. Type: Ginger capsule. Dose: 1 g/day. Duration: 28 days. IG 2: n = 15 at FU. Type: Ginger capsule. Dose: 2 g/day. Duration: 28 days.	n = 14 at FU. Type: Placebo capsule. Dose: NR. Duration: 28 days.	Adverse events: IG: 16.7%. CG: 35.7%. GIS—IBS-SSS (score[b]): IG1: baseline 260.0 ± 65.5, FU: 191.3 ± 95.8, change −68.7 ± 84.3, $P = .007$. IG2: baseline 222.7±53.3, FU: 198.9 ± 88.9, change −23.8 ± 73.9, $P = .233$. CG: baseline 253.2 ± 65.9, FU: 165.0±49.3, change—88.2 ± 78.2, $P = .001$. $P > .05$ between groups.
Ginger (Zingiber officinale)[67]			
DBPCRCT, 3-arms (2 eligible), parallel: Iran, N = 45 (IG1 n = 15, CG n = 15), 0% attrition. IBS: age and sex NR. No funding or COI declared.	IG2: n = 15 FU. Type: Ginger root powder capsule. Dose: 1 g/day. Duration: 20 days.	n = 15 at FU. Type: Placebo (brown sugar) capsule. Dose: NR. Duration: 20 days.	GIS—Abdominal pain severity (score[b]): IG: baseline 39.6 ± 3.29, FU: 31.73 ± 3.21, change −7.9 ± 13.5, $P < .05$. CG: baseline 42.46 ± 2.94, change −4.8 ± 8.7, FU: 37.66 ± 2.89, $P > .05$. GIS—Abdominal distention severity (score[b]): IG: baseline 68.73 ± 3.68, FU: 50.00 ± 2.88. CG: baseline 66.33 ± 2.72, FU: 59.33 ± 2.43. GIS—Constipation severity (score[b]): IG: baseline 70.66 ± 3.09, FU: 49.13 ± 2.7.

Abbreviations: BDS, twice daily; CG, control group; COI, conflict of interest; CRP, c-reactive protein; d, day; DBPCRCT, double blind placebo controlled randomied controlled trial; F, female; FU, follow-up; GIS, gastrointestinal symptoms; IBS, irritable bowel syndrome; IBS-c, irritable bowel syndrome constipation dominant; IBS-d, irritable bowel syndrome diarrhoea dominant; IBS-m, irritable bowel syndrome mixed constipation and diarrhoea; IBS-SSS, irritable bowel syndrome symptom scoring scale; IG, intervention group; IQR, interquartile range; 4ITT, intention to treat; NR, not reported; QDS, four times daily; QOL, quality of life; SF-36, short form 36; TDS, thrice daily; TISS, total IBS symptom score; VAS, visual analogue scale; y, years.

[a]Continuous outcome data reported as mean (μ) ± standard deviation and categorical outcome data reported as number of events/number of participants, unless otherwise specified.

[b]Higher scores indicate worse symptoms.

[c]Higher scores indicate better symptoms.

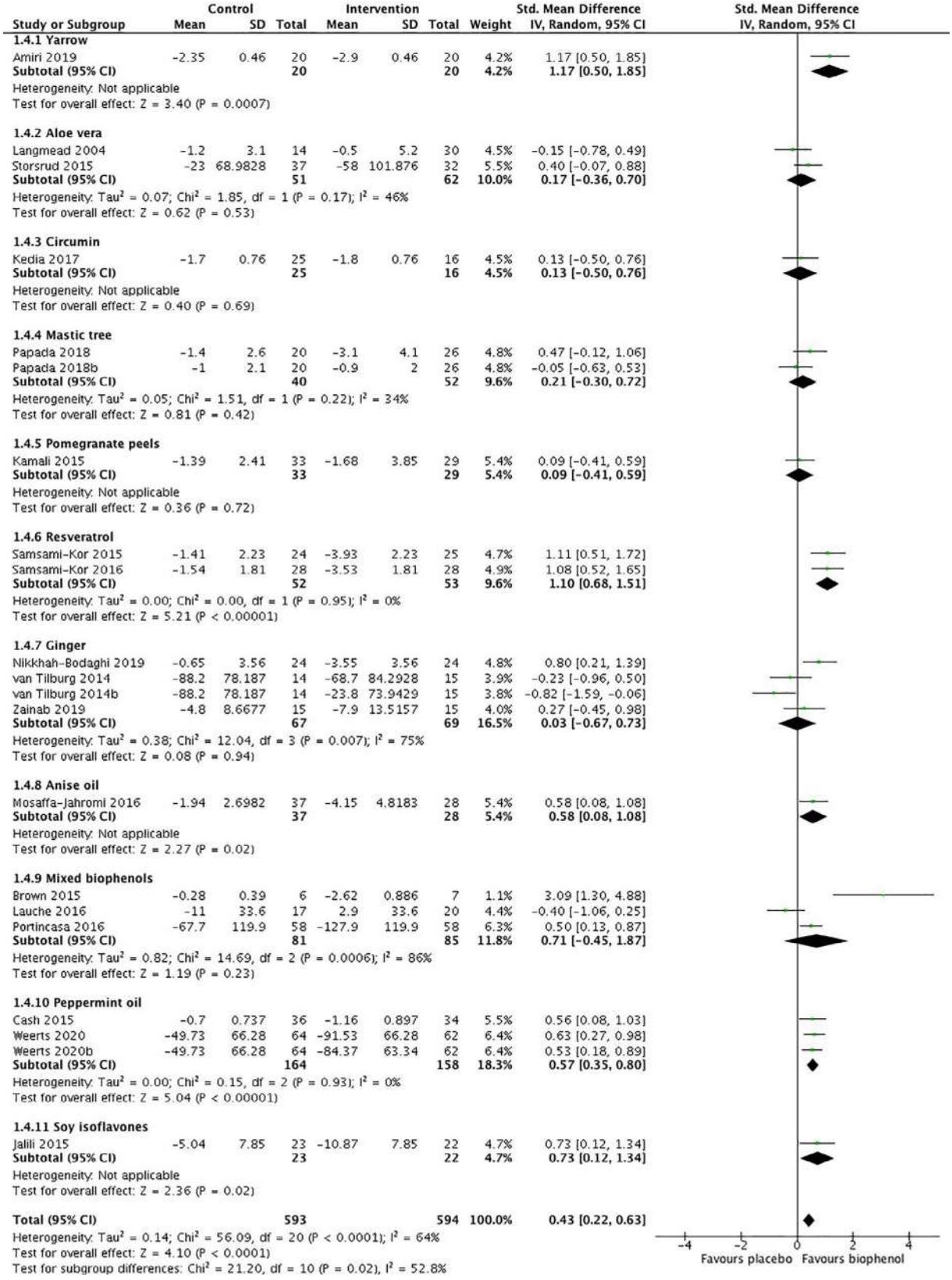

FIGURE 2 Gastrointestinal symptoms of adults with inflammatory bowel disease or irritable bowel syndrome after treatment with biophenol-rich nutraceuticals or placebo per nutraceutical type

substantially improve statistical heterogeneity. GIS were not different according to subgroup by type of condition (IBD vs IBS; $P = .52$). Four studies that recruited participants with IBS measured GIS incidence; all of which reported significant improvements in the intervention (n = 3 studies used peppermint oil, n = 1 study used a mixed biophenol formulation (gelsectan) (Table 2). There were sufficient studies pooled for GIS to generate a funnel plot, which suggests some positive effects of the intervention have not been published (Figure S2).

Subgroup analysis of nutraceutical type found significant differences in GIS between groups ($P = .02$, I^2: 53%). Compared with placebo, peppermint oil significantly improved GIS in participants with IBS with a moderate effect size (SMD: 0.57 [95%CI: 0.35, 0.80], $P < .0001$, I^2: 0%, n = 2 studies, n = 3 intervention groups, n = 322 participants, GRADE: moderate, Figure 2) and resveratrol improved GIS in participants with IBD with a large effect size (SMD: 1.10 [95%CI: 0.68, 1.51], $P < .00001$, I^2: 0%, n = 1 study, n = 2 intervention groups, n = 105 participants, GRADE: moderate, Figure 2). Other nutraceutical types with two or more interventions which showed no significant effect on GIS were *aloe vera* (SMD: 0.17 [95% CI: −0.36, 0.70], $P = .53$, I^2: 46%, n = 2 studies, n = 2 intervention groups, n = 113 participants, GRADE: very low, Figure 2), mastic tree (SMD: 0.21 [95%CI: −0.30, 0.72], $P = .42$, I^2: 34%, n = 1 study, n = 2 intervention groups, n = 92 participants, GRADE: very low, Figure 2), ginger (SMD: 0.03 [95%CI: −0.67, 0.73], $P = .94$, I^2: 75%, n = 3 studies, n = 4 intervention groups, n = 136 participants, GRADE: very low, Figure 2), and mixed biophenols (SMD: 0.71 [95%CI: −0.45, 1.87], $P = .23$, I^2: 86%, n = 3 studies, n = 3 intervention groups, n = 166 participants, GRADE: very low, Figure 2).

Quality of life was mostly measured with condition specific tools such as the Inflammatory Bowel Disease Questionnaire and the Irritable Bowel Syndrome Quality of Life (Table 2). Pooling 12 intervention groups which measured and reported QoL (Tables 1 and 2) found that biophenol-rich nutraceuticals did not improve QoL compared with placebo (SMD: −0.18 [95%CI: −0.41, 0.06], $P = .14$, I^2: 62%; GRADE: very low; Table S3). Condition subgroups were not significantly different (IBD vs IBS; $P = 0.32$); however, a significant subgroup difference was found with nutraceutical type ($P = .002$, Figure S3). Compared with placebo, resveratrol significantly improved QoL in participants with IBD (SMD: −0.84 [95%CI: −1.24, −0.44], $P < .0001$, I^2: 0%, n = 2 studies, n = 2 intervention groups, n = 105 participants, GRADE: high, Figure S3). Other nutraceutical types with two or more interventions, which showed no significant effect on QoL were peppermint oil and mixed biophenols.

No studies which recruited participants with IBS measured inflammatory or oxidative stress markers. The pro-inflammatory marker CRP was reported by four studies (participants with UC: n = 3 studies, UC and CD: n = 1 study). Interventions assessing CRP used yarrow, mastic tree, resveratrol, or *aloe vera*. Compared with placebo, biophenol-rich nutraceuticals significantly improved CRP by 1.6 mg/L (95%CI: 0.08, 3.11; $P = .04$; I^2: 18%, GRADE: low;Table S3, n = 4 studies, n = 4 interventions, n = 193 participants). Compared with placebo, biophenol-rich nutraceuticals (resveratrol (n = 1 study) and ginger (n = 1 study)) significantly improved oxidative stress marker malondialdehyde by 1 mmol/L ([95%CI: 0.55, 1.38]; $P < .00001$; I^2: 0%, n = 2 studies, n = 2 interventions, n = 102 participants; GRADE: low) but had no effect on total antioxidant capacity (SMD: 1.36 [95%CI: −0.24, 1.30], $P = .17$ I^2: 73%, 2 studies, 2 interventions, 102 participants; GRADE: very low). Too few studies were included in these models to conduct a sensitivity analysis. One study reported significant positive effects of resveratrol on inflammatory marker, tumour necrosis factor alpha,[51] and oxidative stress marker, superoxide dismutase.[50] Other oxidative stress markers measured were oxidised LDL, which was significantly improved with mastic tree. Other inflammatory markers measured were IL-6, IL-10, and calprotectin, which showed no significant effect (Table 1).[47,48]

Adverse events were reported in 19 studies. A total of 46 and 80 adverse events were reported in control and intervention groups, respectively; however, when pooled, there was no significant difference between groups (OR: 0.68 [95%CI: 0.40, 1.15], $P = .15$, I^2: 21%; GRADE: low; Table S3). Adverse events were not different according to subgroup by type of condition (IBD vs IBS; $P = .27$) or nutraceutical type ($P = .16$). Adverse events were mild and mostly included gastrointestinal distress. No serious adverse events were reported.

4 | DISCUSSION

This review found that adjuvant biophenol-rich nutraceutical supplementation may improve GIS, inflammation, oxidative stress, and QoL in adults diagnosed with IBD, and GIS in participants diagnosed with IBS. Using the GRADE framework, there was low certainty that the pooled effect sizes represent the true effect due to statistical heterogeneity, publication bias, and/or imprecision. Factors leading to the substantial clinical heterogeneity included varying medical status, pathophysiology of the gastrointestinal condition, and lifestyle of participants as well as the use of different outcome measurement tools and biophenol sources. Subgroup analyses resolved some

sources of heterogeneity, and found high certainty that resveratrol improved QoL in IBD with a large effect size, and moderate certainty that peppermint oil and resveratrol improved GIS with moderate and large effect sizes for IBS and IBD, respectively.

The pooled effect size of all biophenols on GIS was moderate (SMD 0.43), suggesting substantial clinical benefit of intervention, particularly peppermint oil and resveratrol. Despite the use of validated tools in measuring GIS, it is important to recognise that there is no universally accepted endpoint to assess GIS severity. This is due to several factors including the subjectivity of GIS experienced by patients, variations in the types of rating scales such as VAS vs Likert scales, the treatment of scales as continuous or ordinal, and the ceiling and floor effects of different tools.[68] Although the inconsistency found in the pooling of GIS scores across the 21 intervention groups may be contributed to by the pooling of patients with IBS and IBD, two distinct conditions, subgroup analysis did not identify any statistically significant difference in their perceptions of GIS. Publication bias contributed to the decreased certainty in the effect on GIS; however, the direction of bias suggests that the true effect size may be larger than the estimate.

The evidence supporting the use of biophenol-rich nutraceuticals for subjective GIS improvement in IBD is strengthened by the finding of decreased objective inflammatory and oxidative stress biomarkers. Previous studies have shown the effect of biophenol-rich nutraceuticals on improving oxidative stress and inflammation in chronic disease states including liver disease, cardiovascular disease, and kidney disease.[19,27,69] Although only measured by few studies with a limited cumulative sample size and wide confidence intervals, decreasing certainty in the estimated effects, this finding may explain the mechanism by which GIS were improved.[70] Although inflammatory and oxidative stress markers are not consistent biomarkers for IBS, future studies should measure these outcomes to better explore how inflammation and oxidative stress may play a role within IBS subtypes and if these may be modified by biophenols.

Emerging evidence suggests that biophenols may beneficially modulate inflammation, oxidation, and the gut-brain axis via stimulation of the abundance of health promoting bacterial species and inhibition of pathogenic species in the gut.[71] Gut bacteria metabolites are linked to having important roles in reducing inflammation and oxidation as well as maintaining the health of gastrointestinal cells. Furthermore, gastrointestinal conditions such as IBD and IBS have been associated with alterations in the gut microbiota, which is thought to be related to activation of gut pain sensory pathways.[72-74] Gut microbiota are also thought to influence bioavailability and metabolism of biophenols, suggesting that an individual's microbiota profile may influence biophenol treatment efficacy.[71] The gut microbiota play an important role in the gut-brain axis, which involves a bidirectional communication network between the central nervous system and the enteric nervous system. This allows the brain to influence intestinal activities, and the gut to influence mood, cognition, and mental health, which may explain the positive effects of resveratrol biophenols on QoL.[75]

In this review, 19 articles reported adverse events that were mild and GIS-related such as nausea, difficulty passing stools, loose stools, bloating, and heart burn. Meta-analysis found no difference between intervention groups and placebo and these symptoms are also consistent with those that people with IBS and IBD commonly experience due to their underlying disease. Furthermore, no severe adverse events were associated with the intervention, suggesting that biophenol-rich nutraceuticals are safe to be used in patients with IBD and IBS and potential benefits may outweigh possible discomfort. However, due to included studies in this review being of short duration (4-12 weeks), caution should be taken if taken for long-term use.

The evidence identified is limited by small sample sizes of individual studies, and broad clinical heterogeneity of both samples, gastrointestinal pathophysiology, and intervention types. Although conclusions may be drawn about the general effect of biophenol-rich nutraceuticals, the evidence exploring the comparative effects of different types of biophenols is more limited, except for peppermint oil and resveratrol. Likewise, the current evidence is insufficient to determine optimal dosing regimens due to clinical and statistical heterogeneity. Although publication bias was detected for GIS only, it is likely to also exist for other outcomes in which there were insufficient studies to generate funnel plots. Publication bias may have been impacted by the exclusion of otherwise eligible studies on the basis of publication language. Confounding effects of dietary intakes were not reported or accounted for in multivariable models in the identified RCTs. As some studies did not report mean changes or SDs within groups, these values had to be calculated for use in the meta-analysis, and as such, SDs are often overestimated. Finally, this study did not develop GRADE clinical recommendations.

RCTs of longer duration of 6 to 12 months, which explore optimal dosing regimens, and confirm safety are a priority, as are RCTs which deliver interventions to patients with SUDD, and explore the effect of sub-types of IBS. Studies that explore the mechanisms of how biophenols influence biomarkers and clinical presentation

of inflammatory-related gastrointestinal conditions are needed, including exploration of the impact on the microbiome. RCTs should be sufficiently powered or allow for multivariable models to account for confounding factors, including dietary intake and lifestyle.

Biophenol-rich nutraceutical supplementation used as an adjuvant therapy appears safe and may improve GIS, inflammation, oxidative stress, and QoL in patients with IBD and IBS, with higher certainty of evidence for peppermint oil for IBS and resveratrol for IBD. Further research is required to strengthen confidence in the body of evidence, identify ideal dosing regimens, and confirm long-term safety.

CONFLICT OF INTEREST

The authors declare no actual or potential conflicts of interest.

AUTHOR CONTRIBUTIONS

The study concept was developed by Skye Marshall and contributed to by Joanna Giang and Xiao Lan. Joanna Giang and Xiao Lan drafted the manuscript and led the screening, data extraction, quality assessments, meta-analysis, and GRADE assessments. Skye Marshall contributed to screening, meta-analysis, and GRADE assessment. Megan Crichton and Wolfgang Marx contributed to quality assessments and data extraction. All authors contributed to manuscript revision. Skye Marshall provided supervision and oversight to all study components and led the response to peer review.

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REFERENCES

1. Corsetti M, Whorwell P. The global impact of IBS: time to think about IBS-specific models of care? *Therap Adv Gastroenterol*. 2017;10(9):727-736.
2. M'Koma AE. Inflammatory bowel disease: an expanding global health problem. *Clin Med Insights Gastroenterol*. 2013;6:33-47.
3. Yamamoto-Furusho JK, Sarmiento-Aguilar A, Toledo-Mauriño JJ, et al. Incidence and prevalence of inflammatory bowel disease in Mexico from a nationwide cohort study in a period of 15 years (2000-2017). *Medicine (Baltimore)*. 2019;98 (27):e16291-e16291.
4. Saha L. Irritable bowel syndrome: pathogenesis, diagnosis, treatment, and evidence-based medicine. *World J Gastroenterol*. 2014;20(22):6759-6773.
5. Fakhoury M, Negrulj R, Mooranian A, Al-Salami H. Inflammatory bowel disease: clinical aspects and treatments. *J Inflamm Res*. 2014;7:113-120.
6. Kim DH, Cheon JH. Pathogenesis of inflammatory bowel disease and recent advances in biologic therapies. *Immune Netw*. 2017;17(1):25-40.
7. Fengming Y, Jianbing W. Biomarkers of inflammatory bowel disease. *Dis Markers*. 2014;2014:710915.
8. Gallo A, Ianiro G, Montalto M, Cammarota G. The role of biomarkers in diverticular disease. *J Clin Gastroenterol*. 2016;50: S26-S28.
9. Kim JH, Lin E, Pimentel M. Biomarkers of irritable bowel syndrome. *J Neurogastroenterol Motil*. 2017;23(1):20.
10. Eberhardt F, Jenkins-Chapman J, Nucera R, Dalwood P, Canavan R, Marshall S. A lack of knowledge and a fear of food triggers suffering in patients with a history of acute diverticulitis: an interpretative phenomenological analysis. *Clin Nutr*. 2019;38(S1):S180.
11. Buono JL, Carson RT, Flores NM. Health-related quality of life, work productivity, and indirect costs among patients with irritable bowel syndrome with diarrhea. *Health Qual Life Outcomes*. 2017;15(1):35.
12. Gracie DJ, Williams CJ, Sood R, et al. Negative effects on psychological health and quality of life of genuine irritable bowel syndrome–type symptoms in patients with inflammatory bowel disease. *Clin Gastroenterol Hepatol*. 2017;15(3):376-384. e375.
13. Canavan C, West J, Card T. The epidemiology of irritable bowel syndrome. *Clin Epidemiol*. 2014;6:71-80.
14. Eberhardt F, Crichton M, Dahl C, et al. Role of dietary fibre in older adults with asymptomatic (AS) or symptomatic uncomplicated diverticular disease (SUDD): systematic review and meta-analysis. *Maturitas*. 2019.57-67
15. Matsuoka K, Kobayashi T, Ueno F, et al. Evidence-based clinical practice guidelines for inflammatory bowel disease. *Journal of gastroenterology*. 2018;53:305-353.
16. Staudacher HM, Lomer MC, Farquharson FM, et al. A diet low in FODMAPs reduces symptoms in patients with irritable bowel syndrome and a probiotic restores bifidobacterium species: a randomized controlled trial. *Gastroenterology*. 2017;153(4):936-947.
17. Nunan D, Ordóñez-Mena JM, Roberts N, Thomas E, Mahtani K. Physical activity for treatment of irritable bowel syndrome: cochrane systematic review. *Br J Gen Pract*. 2019;69 (suppl 1):bjgp19X703205.
18. Marx W, McCarthy AL, Marshall S, et al. Supplemental prophylactic intervention for chemotherapy-induced nausea and emesis (SPICE) trial: protocol for a multi-centre double-blind placebo-controlled randomized trial. *Nutr Diet*. 2018;77(1): 144-150.
19. Marx W, Kelly J, Marshall S, Nakos S, Campbell K, Itsiopoulos C. The effect of polyphenol-rich interventions on cardiovascular risk factors in haemodialysis: a systematic review and meta-analysis. *Nutrients*. 2017;9(12):1345.
20. Marx W, George ES, Mayr HL, et al. Effect of high polyphenol extra virgin olive oil on markers of cardiovascular disease risk in healthy Australian adults (OLIVAUS): a protocol for a double-blind randomised, controlled, cross-over study. *Nutr Diet*. 2020;77(5):523-528.
21. Obied HK. Biography of biophenols: past, present and future. *Funct Foods Health Dis*. 2013;3(6):230-241.
22. Tsao R. Chemistry and biochemistry of dietary polyphenols. *Nutrients*. 2010;2(12):1231-1246.
23. Chong MF, Macdonald R, Lovegrove JA. Fruit polyphenols and CVD risk: a review of human intervention studies. *Br J Nutr*. 2010;104(Suppl 3):S28-S39.
24. Crichton M, Marshall S, Marx W, McCarthy AL, Isenring E. Efficacy of ginger (*Zingiber officinale*) in ameliorating

chemotherapy-induced nausea and vomiting and chemotherapy-related outcomes: a systematic review update and meta-analysis. *J Acad Nutr Diet*. 2019;119(12):2055-2068.
25. Marx W, Kelly JT, Marshall S, et al. Effect of resveratrol supplementation on cognitive performance and mood in adults: a systematic literature review and meta-analysis of randomized controlled trials. *Nutr Rev*. 2018;76(6):432-443.
26. Travica N, D'Cunha NM, Naumovski N, et al. The effect of blueberry interventions on cognitive performance and mood: a systematic review of randomized controlled trials. *Brain Behav Immun*. 2020;85:96-105.
27. George ES, Marshall S, Mayr HL, et al. The effect of high-polyphenol extra virgin olive oil on cardiovascular risk factors: a systematic review and meta-analysis. *Crit Rev Food Sci Nutr*. 2019;59(17):2772-2795.
28. Karković Marković A, Torić J, Barbarić M, Jakobušić BC. Hydroxytyrosol, tyrosol and derivatives and their potential effects on human health. *Molecules*. 2019;24(10):2001.
29. Yeh W-J, Hsia S-M, Lee W-H, Wu C-H. Polyphenols with antiglycation activity and mechanisms of action: a review of recent findings. *J Food Drug Anal*. 2017;25(1):84-92.
30. Cardona F, Andrés-Lacueva C, Tulipani S, Tinahones FJ, Queipo-Ortuño MI. Benefits of polyphenols on gut microbiota and implications in human health. *J Nutr Biochem*. 2013;24(8):1415-1422.
31. Larussa T, Imeneo M, Luzza F. Potential role of nutraceutical compounds in inflammatory bowel disease. *World J Gastroenterol*. 2017;23(14):2483-2492.
32. Gao X, Liu J, Li L, Liu W, Sun M. A brief review of nutraceutical ingredients in gastrointestinal disorders: evidence and suggestions. *Int J Mol Sci*. 2020;21(5):1822.
33. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med*. 2009;151(4):264.
34. Neveu V, Perez-Jiménez J, Vos F, et al. Phenol-explorer: an online comprehensive database on polyphenol contents in foods. *Database*. 2010;2010.
35. Google. Google translate. https://translate.google.com/ 2017
36. Rathbone J, Carter M, Hoffmann T, Glasziou P. Better duplicate detection for systematic reviewers: evaluation of systematic review assistant-deduplication module. *Syst Rev*. 2015;4:6.
37. EndNote X9 [computer program]. Windows, macOS; 2019.
38. *Covidence Systematic Review Software [computer program]*. Melbourne, Australia: Veritas Health Innovation; 2019.
39. Review Manager Web (RevMan Web) [computer program]. The Cochrane Collaboration; 2019.
40. Higgins JP, Altman DG, Gotzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*. 2011;343:d5928.
41. Smith J, Dransfield A. Patient and carer involvement in healthcare education, service delivery and research: avoiding tokenism. *Evid Based Nurs*. 2019;22(3):65-66.
42. Higgins JPT. Green S. 17.8.2 study summaries using more than one patient-reported outcome. *Cochrane Handbook for Systematic Reviews of Interventions*. Oxford, UK: The Cochrane Collaboration and John Wiley & Sons Ltd; 2011.
43. Schroll JB, Moustgaard R, Gøtzsche PC. Dealing with substantial heterogeneity in Cochrane reviews cross-sectional study. *BMC Med Res Methodol*. 2011;11(1):22.
44. Amiri M, Navabi J, Shokoohinia Y, et al. Efficacy and safety of a standardized extract from Achillea wilhelmsii C. Koch in patients with ulcerative colitis: a randomized double blind placebo-controlled clinical trial. *Complement Ther Med*. 2019;45:262-268.
45. Langmead L, Feakins RM, Goldthorpe S, et al. Randomized, double-blind, placebo-controlled trial of oral *Aloe vera* gel for active ulcerative colitis. *Aliment Pharmacol Ther*. 2004;19(7):739-747.
46. Kedia S, Bhatia V, Thareja S, et al. Low dose oral curcumin is not effective in induction of remission in mild to moderate ulcerative colitis: results from a randomized double blind placebo controlled trial. *World J Gastrointest Pharmacol Ther*. 2017;8(2):147-154.
47. Papada E, Forbes A, Amerikanou C, et al. Antioxidative efficacy of a *Pistacia lentiscus* supplement and its effect on the plasma amino acid profile in inflammatory bowel disease: a randomised, double-blind, placebo-controlled trial. *Nutrients*. 2018;10(11):1779.
48. Papada E, Gioxari A, Amerikanou C, et al. Regulation of faecal biomarkers in inflammatory bowel disease patients treated with oral mastiha (*Pistacia lentiscus*) supplement: a double-blind and placebo-controlled randomised trial. *Phytother Res*. 2019;33(2):360-369.
49. Kamali M, Tavakoli H, Khodadoost M, et al. Efficacy of the *Punica granatum* peels aqueous extract for symptom management in ulcerative colitis patients. A randomized, placebo-controlled, clinical trial. *Complement Ther Clin Pract*. 2015;21(3):141-146.
50. Samsamikor M, Daryani NE, Asl PR, Hekmatdoost A. Resveratrol supplementation and oxidative/anti-oxidative status in patients with ulcerative colitis: a randomized, double-blind placebo-controlled pilot study. *Arch Med Res*. 2016;47(4):304-309.
51. Samsami-Kor M, Daryani NE, Asl PR, Hekmatdoost A. Anti-inflammatory effects of resveratrol in patients with ulcerative colitis: a randomized, double-blind, placebo-controlled pilot study. *Arch Med Res*. 2015;46(4):280-285.
52. Ben-Arye E, Goldin E, Wengrower D, Stamper A, Kohn R, Berry E. Wheat grass juice in the treatment of active distal ulcerative colitis: a randomized double-blind placebo-controlled trial. *Scand J Gastroenterol*. 2002;37(4):444-449.
53. Nikkhah-Bodaghi M, Maleki I, Agah S, Hekmatdoost A. Zingiber officinale and oxidative stress in patients with ulcerative colitis: a randomized, placebo-controlled, clinical trial. *Complement Ther Med*. 2019;43:1-6.
54. Storsrud S, Pontén I, Simren M. A pilot study of the effect of *Aloe barbadensis* mill. Extract (AVH200®) in patients with irritable bowel syndrome: a randomized, double-blind, placebo-controlled study. *J Gastrointest Liver Dis*. 2015;24:275-280.
55. Mosaffa-Jahromi M, Lankarani KB, Pasalar M, Afsharypuor S, Tamaddon A-M. Efficacy and safety of enteric coated capsules of anise oil to treat irritable bowel syndrome. *J Ethnopharmacol*. 2016;194:937-946.
56. Trifan A, Burta O, Tiuca N, Petrisor DC, Lenghel A, Santos J. Efficacy and safety of gelsectan for diarrhoea-predominant irritable bowel syndrome: a randomised, crossover clinical trial. *United Eur Gastroenterol J*. 2019;7(8):1093-1101.
57. Lauche R, Kumar S, Hallmann J, et al. Efficacy and safety of ayurvedic herbs in diarrhoea-predominant irritable bowel

syndrome: a randomised controlled crossover trial. *Complement Ther Med*. 2016;26:171-177.
58. Brown K, Scott-Hoy B, Jennings L. Efficacy of a Quebracho, Conker tree, and M. balsamea Willd blended extract in a randomized study in patients with irritable bowel syndrome with constipation. *J Gastroenterol Hepatol Res*. 2015;4:1762-1767.
59. Portincasa P, Bonfrate L, Scribano ML, et al. Curcumin and fennel essential oil improve symptoms and quality of life in patients with irritable bowel syndrome. *J Gastrointestin Liver Dis*. 2016;25(2):151-157.
60. Cappello G, Spezzaferro M, Grossi L, Manzoli L, Marzio L. Peppermint oil (Mintoil) in the treatment of irritable bowel syndrome: a prospective double blind placebo-controlled randomized trial. *Dig Liver Dis*. 2007;39(6):530-536.
61. Cash B, Epstein M, Shah S, Cash BD, Epstein MS, Shah SM. A novel delivery system of peppermint oil is an effective therapy for irritable bowel syndrome symptoms. *Digest Dis Sci*. 2016;61 (2):560-571.
62. Liu JH, Chen GH, Yeh HZ, Huang CK, Poon SK. Enteric-coated peppermint-oil capsules in the treatment of irritable bowel syndrome: a prospective, randomized trial. *J Gastroenterol*. 1997;32(6):765-768.
63. Weerts Z, Masclee AAM, Witteman BJM, et al. Efficacy and safety of peppermint oil in a randomized, double-blind trial of patients with irritable bowel syndrome. *Gastroenterology*. 2020;158(1):123-136.
64. Merat S, Khalili S, Mostajabi P, Ghorbani A, Ansari R, Malekzadeh R. The effect of enteric-coated, delayed-release peppermint oil on irritable bowel syndrome. *Dig Dis Sci*. 2010; 55(5):1385-1390.
65. Jalili M, Vahedi H, Janani L, Poustchi H, Malekzadeh R, Hekmatdoost A. Soy isoflavones supplementation for patients with irritable bowel syndrome: a randomized double blind clinical trial. *Middle East J Dig Dis*. 2015;7:170-176.
66. van Tilburg MA, Palsson OS, Ringel Y, Whitehead WE. Is ginger effective for the treatment of irritable bowel syndrome? A double blind randomized controlled pilot trial. *Complement Ther Med*. 2014;22(1):17-20.
67. Al-Jassim ZG. Using brewer's yeast and ginger in the management of constipation-predominant irritable bowel syndrome: a randomized double-blind placebo-controlled trial. *Asian J Pharm Clin Res*. 2019;12(3):372-376.
68. Miller LE. Study design considerations for irritable bowel syndrome clinical trials. *Ann Gastroenterol*. 2014;27(4):338-345.
69. Faghihzadeh F, Hekmatdoost A, Adibi P. Resveratrol and liver: a systematic review. *J Res Med Sci*. 2015;20(8):797-810.
70. Schoepfer AM, Vavricka S, Zahnd-Straumann N, Straumann A, Beglinger C. Monitoring inflammatory bowel disease activity: clinical activity is judged to be more relevant than endoscopic severity or biomarkers. *J Crohn's Colitis*. 2012; 6(4):412-418.
71. Ma G, Chen Y. Polyphenol supplementation benefits human health via gut microbiota: a systematic review via meta-analysis. *J Funct Foods*. 2020;66:103829.
72. Dupont HL. Review article: evidence for the role of gut microbiota in irritable bowel syndrome and its potential influence on therapeutic targets. *Aliment Pharmacol Ther*. 2014;39(10):1033-1042.
73. Kennedy PJ, Cryan JF, Dinan TG, Clarke G. Irritable bowel syndrome: a microbiome-gut-brain axis disorder? *World J Gastroenterol*. 2014;20(39):14105-14125.
74. Mayer EA, Savidge T, Shulman RJ. Brain-gut microbiome interactions and functional bowel disorders. *Gastroenterology*. 2014;146(6):1500-1512.
75. Cryan JF, O'Riordan KJ, Cowan CSM, et al. The microbiota-gut-brain axis. *Physiol Rev*. 2019;99(4):1877-2013.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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REVIEW

Behaviour change theories and techniques used to inform nutrition interventions for adults undergoing bariatric surgery: A systematic review

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Abstract

Aim: This systematic review aimed to describe behaviour change theories and techniques used to inform nutrition interventions for adults undergoing bariatric surgery.

Methods: A systematic search was conducted across PubMed, PsycInfo, CENTRAL, EMBASE and CINAHL from inception until 09 March 2021. Eligible studies were randomised controlled trials involving nutrition interventions performed by a healthcare provider, to adults that were waitlisted or had undergone bariatric surgery and received a nutrition intervention explicitly informed by one or more behaviour change theories or behaviour change techniques. Screening was conducted independently by two authors. Behaviour change techniques were examined using the behaviour change technique taxonomy version one which includes 93 hierarchical techniques clustered into 16 groups. Quality of included studies was assessed using Cochrane risk of bias 2.0.

Results: Twenty-one publications were included, involving 15 studies and 14 interventions, with 1495 participants. Bias was low or had some concerns. Two interventions reported using behaviour change theories (transtheoretical model and self-determination theory). Thirteen behaviour change technique taxonomy groupings and 29 techniques were reported across 14 interventions. Common techniques included '1.2 Problem solving' ($n = 9$ studies), '3.1 Social support (unspecified)' ($n = 9$ studies), '1.1 Goal setting (behaviour)' ($n = 6$ studies) and '2.3 Self-monitoring of behaviour' (n =- 6 studies).

Conclusion: While behaviour change techniques have been included, behaviour change theory is not consistently reported and/or adopted to inform nutrition interventions for adults undergoing bariatric surgery. Integrating behaviour change theory and techniques in nutrition interventions is important for researchers and bariatric surgery teams, including dietitians, to effectively target behaviours for this population.

KEYWORDS

bariatric surgery, behavior change technique, behaviour change theory, behavioural research, nutrition intervention, systematic literature review

1 | INTRODUCTION

An increasing number of individuals are presenting for weight loss treatment, and bariatric surgery is recognised as an effective option.[1] In Australia, there has been a 2.4-fold increase with 9300 surgeries performed during the financial year 2005/2006 and 21043 in 2018/2019.[2,3] In this field, the care team, including dietitians, work with patients to navigate post-operative nutritional recommendations, identify history or re-emergence of disordered eating with on-going dietary monitoring, recognise mental health factors and employ counselling and behaviour change.[4] The National Health and Medical Research Council highlights the need for additional post-operative lifestyle management support and recommends behaviour change strategies as integral.[5]

There is a substantial proportion of bariatric surgery patients who experience weight regain or insufficient weight loss.[1] Behavioural predictors of weight regain include increased food urges, decreased well-being and concerns over alcohol or drug use.[6] Additional risk factors include anxiety, binge eating, emotional eating, portion size and sugary food and drink consumption.[7] Willingness to change habits, self-esteem, social support and quality of life are negatively associated with post-operative weight regain.[7]

Behaviour change theories help to identify potentially effective content for interventions and the processes by which that content is thought to change behaviour.[8] It is important to consider the link between intervention content and the theoretical constructs through which the content is proposed to exert effects. Intervention content is commonly based on a set of behaviour change techniques.[8] Understanding the mechanisms through which these techniques can modify behaviour is important for the development and evaluation of effective behavioural interventions.

Behaviour change interventions can be complex and interacting components can make it difficult to replicate in research and practically apply.[9] There have been efforts to standardis the reporting of behaviour change interventions and their theoretical underpinnings,[9] which may facilitate communication across disciplines, and strengthen intervention replication and implementation. The behaviour change technique taxonomy, for example, provides a standardised classification system of intervention techniques.[9] Furthermore, frameworks such as intervention mapping,[10] the PRECEDE–PROCEED model,[11] and the behaviour change wheel,[12] further support the transition from theory to intervention. Understanding the active components of interventions is essential for translating evidence-based interventions into practice; however, this depends on the available body of evidence.[9] This systematic review aimed to describe behaviour change theories and techniques used to inform nutrition interventions for adults undergoing bariatric surgery.

2 | METHODS

This systematic literature review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement,[13] and was prospectively registered with PROSPERO (CRD42021240813).

Studies were searched across five electronic databases: PubMed (including MEDLINE), PsycInfo (via Ovid), CENTRAL, EMBASE and CINAHL (via EBSCOhost) from database inception up until 09 March 2021. The search strategy used a combination of keywords and translated to the other databases using CREBP-SRA Polyglot Search Translator (Table S1).[14] Translated search terms were checked for accuracy and modified after assessment for each database. An experienced systematic review search librarian was consulted throughout the search execution. There were no language restrictions applied. Reference lists of all included articles and relevant systematic reviews were screened to identify any additional studies.

To be eligible for inclusion, each study had to satisfy the inclusion criteria regarding population, intervention, comparison, outcome and study design. Eligible studies were randomised controlled trials involving nutrition interventions performed by a bariatric surgery healthcare provider, to adults (≥18 years) that were waitlisted or had undergone bariatric surgery, and received a nutrition intervention explicitly informed by one or more behaviour change theories or behaviour change techniques. Bariatric procedures considered were any open, laparoscopic or endoscopic procedure used to manage obesity. Behaviour change theories include ecological model, health action process approach, health belief model, integrated theories, model of action phases, protection motivation theory, self-determination theory, social cognitive theory, theory of planned behaviour, and trans-theoretical model. Comparison needed to be usual care or minimal care (nutrition-related print materials, information booklets or information regarding the individual's health status) without the use of behaviour change theory or no intervention delivered. In addition, at least one of the following outcomes needed to be included; eating behaviours, dietary intake (measured with a validated assessment tool), anthropometric measures, clinical measures, or psychological outcomes. Conference papers, dissertations, abstracts without full text and protocol papers where it was not possible to identify a published result paper were excluded.

Duplicate records were removed using Endnote (version 9.3.3). Records were screened for potentially eligible studies based on title and abstract by two independent investigators. Full texts were reviewed to confirm eligibility by two independent investigators; disagreements were managed by consensus or a third reviewer when required.

Data were extracted by one researcher, checked for accuracy by a second researcher and any discrepancies were corrected through discussion. Data extracted included author, publication date, country, study design, setting, participant characteristics (age, gender and preoperative body mass index), intervention characteristics (detail, duration, delivery personnel), control characteristics (detail, duration, delivery personnel), behaviour change theory and techniques, study aim, primary outcomes as listed in the published papers and associated measures of effectiveness. Data were extracted, tabulated and synthesised narratively.

Behaviour change techniques applied in the interventions were examined using the behaviour change technique taxonomy version one.[9,15] The behaviour change technique taxonomy is considered the standard for reporting on techniques in health behaviour change literature,[16] and includes 93 hierarchical techniques clustered into 16 groups.[9,15] The behaviour change technique taxonomy includes a descriptions table which denotes a number, label, definition and examples for each technique; demonstrated in Table S2. The groups within the behaviour change technique taxonomy do not have definitions or examples associated with them.

The full text of the included reports and additional relevant supplementary material or protocols were uploaded into NVivo.[17] Intervention details within the manuscripts, tabulated results and supplementary material were analysed and coded. If the intervention was reported to be described in a prior publication, this publication was sourced and coded. One researcher initially coded behaviour change techniques according to exact phrases and specific terminology included in the behaviour change technique taxonomy description table (demonstrated in Table S2); herein referred to as 'objective' coding. The consistency of the coding was checked by a second researcher (a behavioural scientist). If techniques could not be coded according to exact phrases and specific terminology; yet, subjectively were able to be interpreted as being consistent with the behaviour change technique taxonomy, a 'subjective' code was applied by one researcher. This was checked by the second researcher, and any disagreements were resolved through discussion.

When studies explicitly reported a group rather than individual behaviour change techniques, for example, '1.0 Goals and planning', an objective code was applied to that group. Some studies described intervention components that could not be mapped to individual behaviour change techniques yet were subjectively determined to fit within a group. For example, an intervention providing psychoeducation on body image would be subjectively coded to the group '4.0 Shaping knowledge' as it did not meet the exact criteria to be coded as any of the behaviour change techniques under this group. Criteria were formed to provide some systematic approach to the subjective coding to groupings (Table 1). The frequency and total number of behaviour change techniques used in each study only include techniques that were determined through objective coding and do not include those coded subjectively. Techniques that were ambiguous and could not be mapped to the behaviour change technique taxonomy were coded as 'unspecified'.

Studies were assessed for risk of bias using the Cochrane risk of bias 2.0 tool,[18] by two investigators independently, with disagreements managed by consensus. The risk of bias in the domain of 'bias in measurement of the outcome' depends on whether the method of measuring the outcome is appropriate, whether measurement or ascertainment of the outcome differs or could differ between intervention groups, who is the outcome

assessor, whether the outcome assessor is blinded to intervention assignment and whether the assessment of outcome is likely to be influenced by knowledge of intervention received. The primary outcomes as listed in the published papers were extracted and the risk of bias applies to these outcomes. Within the present study, our primary interest is the reported behaviour change theories and techniques.

3 | RESULTS

The flow of study identification and selection is detailed in Figure 1. The search identified 6474 publications. Twenty-one reports were included, involving 15 studies and 14 interventions. Two separate studies utilised the same intervention, one delivering the intervention pre-operatively and the other post-operatively.[19,20]

TABLE 1 Taxonomy grouping and related criteria to allow intervention components to be coded despite not directly mapping to one of the behaviour change techniques under each grouping

No	Group label[a]	Criteria
4.0	Shaping knowledge	Related to knowledge,[52] and includes psychoeducation.
5.0	Natural consequences	May include the word consequences and includes implications.
7.0	Associations	Relating to cues and cue responses,[52] and includes triggers.
10.0	Reward and threat	Relating to the anticipation of a direct reward or punishment.[52]
15.0	Self-belief	Beliefs about capabilities and optimism.[52]

[a]While there are 16 groupings in the behaviour change technique taxonomy,[9] the establishment of criteria was only required for five groupings.

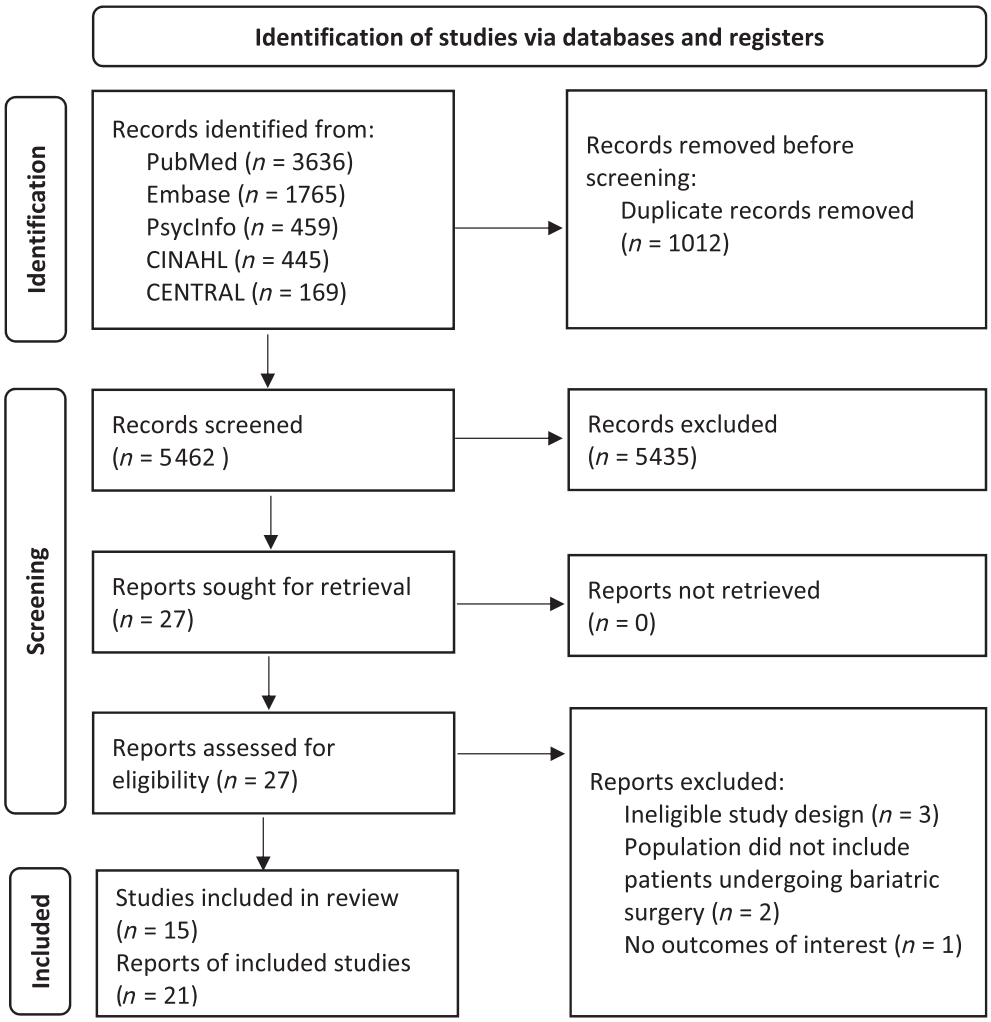

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analysis flowchart,[13] of the literature search and filtering results for a systematic review of interventions delivered in bariatric health care that are informed by behaviour change theories or techniques

TABLE 2 Characteristics of studies with interventions delivered in bariatric health care and informed by behaviour change theories or techniques compared with controls underpinned by no theory, usual/minimal care or having received no contact

Author, year	Population: sample size; retention at longest follow up; age mean ± SD; % female; pre-operative body mass index (BMI)	Intervention: detail; duration and intensity; delivery personnel	Control: detail; duration; delivery personnel	Behaviour change theory; total number of behaviour change techniques
Pre-operative intervention (n = 3, 3 interventions)				
Camolas et al.,[39] 2017	Sample size: $N = 94$ (Intervention $n = 45$, Control $n = 49$) Retention: 64% Age: Intervention 46.3 ± 13.7 years, Control 43.5 ± 13.9 years Gender: 81% female BMI: Intervention 42.8 ± 5.0 kg/m^2, Control 43.5 ± 7.0 kg/m^2	Pre-operative lifestyle focused nutritional intervention; 4 × bimonthly consultations; nutritionist	Minimal care; 2 × sessions; nutritionist	Transtheoretical model and self-determination theory; behaviour change techniques $n = 6$
Cassin et al.,[19] 2016[a]	Sample size: $N = 47$ (Intervention $n = 23$, Control $n = 24$) Retention: 75% Age: 45.5 ± 8.9 years Gender: 83% female BMI: 53.1 ± 12.0 kg/m^2	Pre-operative telephone-based cognitive behavioural therapy; 6 × weekly sessions of 55 min; 2 × Master-level psychometrists	Usual care; duration and delivery personnel not detailed	No theory; behaviour change techniques $n = 24$
Paul et al.,[30] 2021	Sample size: $N = 130$ (Intervention $n = 65$, Control $n = 65$) Retention: 82% Age: 41.7 ± 9.7 years Gender 74% female BMI: Intervention 42.7 ± 5.0 kg/m^2, Control 43.4 ± 5.4 kg/m^2	Pre-operative cognitive behavioural therapy sessions; 10 × weekly sessions of 45-min duration; delivery personnel not detailed	Usual care; duration and delivery personnel not detailed	No theory; behaviour change techniques $n = 14$
Pre- and post-operative intervention (n = 3, 2 interventions)				
Kalarchian et al.,[26] 2013 and Kalarchian et al.,[22] 2016	Sample size: $N = 240$ (Intervention $n = 121$, Control $n = 119$) Retention: 60% Age: 44.9 ± 11.0 years Gender: 90% female BMI: 45.5 ± 6.3 kg/m^2	Pre-operative behavioural lifestyle intervention; 6 months, comprising 24 weekly contacts $n = 12$ face-to-face and $n = 12$ telephone and 3 × monthly telephone contacts post-operatively; delivery personnel not detailed	Usual care; 6 months; delivery personnel not detailed	No theory; behaviour change techniques $n = 20$

TABLE 2 (Continued)

Author, year	Population: sample size; retention at longest follow up; age mean ± SD; % female; pre-operative body mass index (BMI)	Intervention: detail; duration and intensity; delivery personnel	Control: detail; duration; delivery personnel	Behaviour change theory; total number of behaviour change techniques
Ogden et al.,[29] 2015	Sample size: $N = 162$ (Intervention $n = 82$, Control $n = 80$) Retention: 90% Age: 45.2 ± 10.8 years Gender: 75% female BMI: 50.7 ± 7.8 kg/m^2	Pre- and post-operative usual care plus a health psychology led bariatric rehabilitation service; 3 × individual sessions of 50-min durations; health psychologist	Usual care; 12 months; dietitian or specialist nurse	No theory; behaviour change techniques $n = 2$
Post-operative intervention ($n = 15$, 10 interventions)				
Cassin et al.,[20] 2020[a]	Sample size: $N = 122$ (Intervention $n = 61$, Control $n = 61$) Retention: 82% Age: 48.4 ± 8.5 years Gender: 82% female BMI: not specified	Post-operative telephone-based cognitive behavioural therapy; 6 × weekly sessions of 60 min and 1 × 60-min 'booster' session 1 month after the 6th session; 4 × clinical psychology graduate students	Usual care; duration and delivery personnel not detailed	No theory; behaviour change techniques $n = 25$
Chacko et al.,[21] 2016	Sample size: $N = 18$ (Intervention $n = 9$, Control $n = 9$) Retention: 100% Age: Intervention 53.4 ± 5.6 years, Control 54.5 ± 7.8 years Gender: 84% female BMI: Intervention 32.3 ± 6.2 kg/m^2, Control 36.6 ± 8.0 kg/m^2	Post-operative mindfulness-based intervention; 10 × weekly sessions of 90 min; a qualified mindfulness instructor	Usual care; 60 min session; dietitian	No theory; behaviour change techniques $n = 12$
David et al.,[28] 2016	Sample size: $N = 51$ (Intervention $n = 23$, Control $n = 28$) Retention: 86% Age: 49.2 ± 9.1 years Gender: 87% female BMI: not specified	Post-operative adapted motivational interviewing session; 1 × session of 107.9 ± 26.3 min; Master's level clinical psychology student	Waitlist control group; 12 weeks; delivery personnel not detailed	Transtheoretical model; behaviour change techniques $n = 11$
Gade et al.,[37] 2014, Gade et al.,[38] 2015 and Hjelmesæth et al.,[36] 2019	Sample size: $N = 102$ (Intervention $n = 50$, Control $n = 52$) Retention: 60% Age: 42.4 ± 10.1 years Gender: 70% female BMI: 43.5 ± 4.4 kg/m^2	Post-operative cognitive behavioural therapy intervention; 10 weeks $n = 5$ via face to face and $n = 6$ via telephone; delivery personnel not detailed	Usual care; duration not detailed; medical doctor, dietitian, nurse or physical therapist	No theory; behaviour change techniques $n = 10$

(Continues)

TABLE 2 (Continued)

Author, year	Population: sample size; retention at longest follow up; age mean ± SD; % female; pre-operative body mass index (BMI)	Intervention: detail; duration and intensity; delivery personnel	Control: detail; duration; delivery personnel	Behaviour change theory; total number of behaviour change techniques
Lauti et al.,[35] 2018	Sample size: $N = 95$ (Intervention $n = 47$, Control $n = 48$) Retention: 89% Age: Intervention 47.0 ± 8.8 years, Control 45.6 ± 7.2 years Gender 74% female BMI: Intervention 42.4 ± 6.0 kg/m^2, Control 42.5 ± 7.9 kg/m^2	Post-operative text messages based on behaviour change techniques; daily for 12 months; delivery personnel not detailed	Usual care; 12 months; delivery personnel not detailed	No theory; behaviour change techniques $n = 12$
Lent et al.,[23] 2019	Sample size: $N = 50$ (Intervention $n = 24$, Control $n = 26$) Retention 82% Age: Intervention 47.6 ± 9.1 years, Control 46.2 ± 12.0 years Gender: 82% female BMI: Intervention 47.1 ± 6.7 kg/m^2, Control 50.4 ± 6.2 kg/m^2	Post-operative behavioural intervention based on cognitive behavioural therapy; 8 × 60-min group sessions over 16 weeks; co-led by a licenced clinical psychologist or doctoral-level psychology trainee	Usual care; duration and delivery personnel not detailed	No theory; behaviour change techniques $n = 15$
Nijamkin et al.,[24] 2012 and Nijamkin et al.,[27] 2013	Sample size: $N = 144$ (Intervention $n = 72$, Control $n = 72$) Retention 92% Age: 44.5 ± 13.5 years Gender: 83% female BMI: Intervention 35.4 ± 5.3 kg/m^2, Control 36.5 ± 6.4 kg/m^2	Post-operative comprehensive nutrition education and behaviour modification intervention; 6 × fortnightly group sessions of 90-min duration; registered dietitian and psychologist	Minimal care; 6 months; delivery personnel not detailed	No theory; behaviour change techniques $n = 13$
Sarwer,[25] 2012	Sample size: $N = 84$ (Intervention $n = 41$, Control $n = 43$) Retention: 46% Age: 42.0 ± 9.9 years Gender: 63% female BMI: 51.6 ± 9.2 kg/m^2	Post-operative in-person dietary counselling; 8 × fortnightly sessions of 15-min duration (face to face or telephone—participant preference); registered dietitian	Usual care; duration not detailed; dietitian	No theory; behaviour change techniques $n = 2$

TABLE 2 (Continued)

Author, year	Population: sample size; retention at longest follow up; age mean ± SD; % female; pre-operative body mass index (BMI)	Intervention: detail; duration and intensity; delivery personnel	Control: detail; duration; delivery personnel	Behaviour change theory; total number of behaviour change techniques
Weineland et al.,[32] 2012 and Weineland et al.,[31] 2012	Sample size: $N = 39$ (Intervention $n = 19$, Control $n = 20$) Retention: 74% Age: Not described Gender: 90% female BMI: Mean 37 (range 31–47) kg/m^2	Post-operative acceptance and commitment therapy; 2 × face to face sessions, plus a 6-week treatment via the internet, plus 6 × weekly telephone session of a 30-min duration; nurse and a nutritionist	Usual care; duration not detailed; operating-surgeon, bariatric nurse and specialised dietitian.	No theory; behaviour change techniques $n = 7$
Wild et al.,[34] 2015 and Wild et al.,[33] 2017	Sample size: $N = 117$ (Intervention $n = 59$, Control 58) Retention: 63% Age: Intervention 41.4 ± 8.8 years, Control 41.3 ± 9.8 years Gender: 69% female BMI: Intervention 35.2 ± 6.3 kg/m^2, Control 35.0 ± 6.3 kg/m^2 (at baseline)	Post-operative psychoeducational videoconferencing-based group intervention 5 × face-to-face group interventions (≤6 patients, for 90 min each), 6 × videoconferencing sessions in smaller groups (3 patients, 50 min each) and 3 × face-to-face group sessions over 12 months; delivery personnel not detailed	Usual care; duration not detailed; surgeon	No theory; behaviour change techniques $n = 9$

Abbreviations: BMI, body mass index; SD, standard deviation; y, years.

[a]While Cassin et al. (2016) and Cassin et al. (2020) are different in that one was delivered pre-operatively,[19] and the other post-operatively,[20] they both used the same intervention.

TABLE 3 Setting, study aim, primary outcomes, measures and significant results for a systematic review on interventions delivered by one or more bariatric surgery healthcare provider in bariatric health care and informed by behaviour change theories compared with controls underpinned by no theory, usual/minimal care or having received no contact

Author, year	Setting	Study aim	Primary outcome(s)[a] and measure(s)	Intervention effect compared to control[b]
Pre-operative intervention				
Camolas et al.,[39] 2017	Obesity treatment unit of a hospital	'Evaluate the effect of a pre-operative life-style focused nutritional intervention on weight and metabolic control and the impact of the intervention on psychosocial variables associated with successful weight-control'.	Weight and metabolic control indicators via body mass index (BMI), total weight loss (TWL%), excess weight loss (EWL%), fasting insulin and glycaemia and HbA1c at the end of the intervention which was 6 months	↓ BMI ($p = 0.001$) ↑ TWL% ($p = 0.001$) ↑ EWL% ($p = 0.001$) ↓ fasting glycaemia ($p = 0.019$) ≠ fasting insulin ($p \geq 0.05$) ≠ HbA1c ($p \geq 0.05$)
Cassin et al.,[19] 2016	Bariatric surgery programme	'Examine the efficacy of a pre-operative telephone-based CBT intervention versus standard pre-operative care for improving eating psychopathology and psychosocial functioning'.	Eating psychopathology via binge eating scale (BES) and emotional eating scale (EES) at the end of the intervention which was 6 weeks	↓ BES ($p = 0.01$) ↓ EES ($p = 0.002$)
Paul et al.,[30] 2021	A community mental health centre and two general hospitals.	'Investigate the added value of 10 sessions of CBT [cognitive behavioural therapy] prior to bariatric surgery compared to the standard preparation/treatment-as-usual procedure in the hospital for long-term maintenance of weight loss and psychological well-being'.	NR; BMI and weight change by TWL%, eating behaviour via Dutch eating behaviour questionnaire (DEBQ), eating disorders via eating disorder examination questionnaire (EDE-Q), depressive symptoms via the quick inventory of depressive symptomatology (QIDS-SR), quality of life via the World Health Organization quality of life assessment (WHOQoL-BREF), psychological distress via brief symptom inventory (BSI) and global severity index (GSI), at the end of the intervention which was 10 weeks and at 1-year follow-up	≠ BMI ($p \geq 0.05$) ≠ TWL% ($p \geq 0.05$) ≠ DEBQ ($p \geq 0.05$) ≠ EDE-Q ($p \geq 0.05$) ≠ QIDS-SR ($p \geq 0.05$) ≠ WHOQoL-BREF ($p \geq 0.05$) ≠ BSI and GSI ($p \geq 0.05$) For both 10 weeks and 1-year follow-up
Pre- and post-operative intervention				
Kalarchian et al.,[26] 2013 (initial study)	Bariatric Centre of Excellence at a large, urban medical centre	'Document pre-operative outcomes of a behavioural lifestyle intervention delivered to patients prior to bariatric surgery in comparison to treatment as usual'.	NR; TWL (kg), BMI, depression via Beck's depression inventory (BDI), binge eating via the overeating section on the eating disorder examination (EDE-Q), eating behaviours via eating behaviour inventory (EBI), at the end of the intervention which was 6 months	↑ TWL (kg) ($p < 0.0001$) ≠ BDI ($p = 0.54$) ≠ EDE-Q for subjective ($p = 0.47$) and objective ($p = 0.72$) bulimic episodes ↑ EBI ($p = 0.0004$)

TABLE 3 (Continued)

Author, year	Setting	Study aim	Primary outcome(s)[a] and measure(s)	Intervention effect compared to control[b]
Kalarchian et al.,[22] 2016 (follow up study)	Bariatric Centre of Excellence at a large, urban medical centre	'Evaluate whether a pre-surgery behavioural lifestyle intervention improves weight loss through 24 months post-surgery'.	NR; TWL (kg) at 6, 12 and 24 months post-operatively	≠ TWL (kg) at 6 months ($p = 0.12$) and 12 months ($p = 0.12$) ≠ TWL (kg) at 24 months ($p = 0.02$)[c]
Ogden et al.,[29] 2015	Hospital	'Evaluate the impact of a health psychology-led bariatric rehabilitation service (BRS) on patient weight loss following bariatric surgery at 1 year'.	BMI and change in BMI at the end of the intervention which was 12 months	≠ BMI ($p = 0.5$)
Post-operative intervention				
Cassin et al.,[20] 2020	Health network and hospital bariatric surgery programmes	'Examine correlates of food addiction among post-operative bariatric surgery patients; compare the clinical characteristics of patients who meet "diagnosis" for food addiction at 1-year post-surgery to those who do not; and examine whether Tele-CBT improves food addiction symptomatology among the subset of individuals who meet "diagnosis" for food addiction at 1-year post-surgery'.	NR; food addiction symptomatology via modified Yale Food Addiction Scale 2.0 (mYFAS 2.0) at post-intervention (3 months duration which equated to 15 months post-operative) and 18 months post-operatively (3 months post-intervention)	↓ mYFAS 2.0 symptom scores ($p = 0.027$) post-intervention ≠ mYFAS 2.0 symptom scores at follow-up ($p = 0.772$).
Chacko et al.,[21] 2016	Weight loss surgery centre at a medical centre	'Develop and test a novel mindfulness-based intervention designed to control weight after bariatric surgery'.	Feasibility and acceptability via recruitment goals, willingness to participate, adherence rate, retention, at the end of the intervention which was 10 weeks	Recruitment numbers ($n = 18$) were just below target of 20 58% willing to participate Adherence and retention were reported as excellent
David et al.,[28] 2016	Hospital bariatric surgery programme	'Examine the acceptability, feasibility and preliminary efficacy of adapted motivational interviewing for improving self-efficacy and eating behaviours in post-operative bariatric surgery patients'.	NR; Self-efficacy via Ontario bariatric eating self-efficacy (OBESE scale), readiness for change via change ratings, guideline adherence via a checklist and visual analogue scale (VAS), binge eating via BES at 12 weeks follow-up	≠ OBESE scale ≠ change rating for importance of change ≠ change rating for readiness for change ↑ change rating for confidence for change ($p < 0.05$) ≠ dietary adherence via checklist ↑ dietary adherence via VAS ($p < 0.05$) ↓ BES ($p < 0.01$)

(Continues)

TABLE 3 (Continued)

Author, year	Setting	Study aim	Primary outcome(s)[a] and measure(s)	Intervention effect compared to control[b]
Gade et al.,[37] 2014 (initial study)	Tertiary care centre	'Examine whether CBT alleviates dysfunctional eating patterns and symptoms of anxiety and depression in morbidly obese patients planned for bariatric surgery.'	Dysfunctional eating via three-factor eating questionnaire (TFEQ-R21) at the end of the intervention which was 10 weeks	↓ TFEQ-R21 ($p \leq 0.001$)
Gade et al.,[38] 2015 (follow up study 1)	Tertiary care centre	'Examine whether a pre-operative CBT intervention exceeds usual care in the improvements of dysfunctional eating behaviours, mood, affective symptoms and body weight 1 year after bariatric surgery'.	NR; Body weight, dysfunctional eating behaviours via TFEQ-R21 and anxiety and depression via the hospital anxiety and depression scale (HADS) at 1-year follow-up	≠ weight at 1-year follow-up ($p > 0.05$) ≠ TFEQ-R21 at 1-year follow-up ($p > 0.05$) ≠ HADS at 1-year follow-up ($p > 0.05$)
Hjelmesæth et al.,[36] 2019 (follow up study 2)	Tertiary care centre	'Assess the 4-year effects of CBT before bariatric surgery on weight loss, eating behaviours, affective symptoms and health-related quality of life'.	Dysfunctional eating behaviours via TFEQR-21 at 4-year follow-up	≠ TFEQ-R21 at 4-year follow-up ($p > 0.05$)
Lauti et al.,[35] 2018	Public tertiary level hospital outpatient clinic	'Determine the effectiveness of text message support in reducing weight regain following sleeve gastrectomy'.	EWL% at mid intervention (6 months) and at the end of the intervention period (12 months).	≠ EWL% at 6 months ($p = 0.273$) and 12 months ($p = 0.456$)
Lent et al.,[23] 2019	A large, integrated rural health system	'Evaluate the feasibility of a post-operative behavioural intervention programme'.	Feasibility and health-related quality via 36-item short-form survey (SF-36) at the end of the intervention which was 16 weeks	↑ SF-36 social functioning domain only (Cohen's $d = 0.69$)
Nijamkin et al.,[24] 2012	Bariatric laparoscopic institution	'Examine whether a comprehensive nutrition education and behaviour modification intervention improves weight loss and physical activity in Hispanic Americans with obesity following Roux-en-Y gastric bypass surgery'.	EWL% and physical activity involvement via a self-reported questionnaire based on the Short Questionnaire to Assess Health Enhancing Physical Activity (SQUASH) at 6 months follow-up (12 months post-operatively)	↑ EWL ($p < 0.001$). ↑ involvement in physical activity ($p < 0.001$)
Nijamkin et al.,[27] 2013	Bariatric laparoscopic institution	'Evaluate the effect of 2 post-bariatric support interventions on depressive symptoms of Hispanic Americans treated with gastric bypass for morbid or severe obesity'.	Depressive symptoms via BDI-II, and weight change via EWL% at 6 months follow-up (12 months post-operatively)	↓ BDI-II ($p < 0.001$) ↑ EWL% loss ($p < 0.001$)

TABLE 3 (Continued)

Author, year	Setting	Study aim	Primary outcome(s)[a] and measure(s)	Intervention effect compared to control[b]
Sarwer,[25] 2012	Academic medical centre	'Investigate the hypothesis that the provision of post-operative dietary counselling, delivered by a registered dietitian, would lead to greater weight loss and more positive improvements in dietary intake and eating behaviour compared with standard post-operative care'.	TWL% at 2, 4, 6, 12, 18 and 24 months after surgery.	≠ TWL% ($p = 0.08$) at all timepoints
Weineland et al.,[32] 2012 (initial study)	A local centre for minimally invasive surgery	'Evaluate the effects of ACT [acceptance and commitment therapy] for patients who underwent bariatric surgery, with regard to emotional eating, body dissatisfaction and quality of life.'	NR; Eating disordered behaviour via eating disorder examination questionnaire (EDE-Q), binge eating via subjective binge eating questionnaire (SBEQ), pre-occupation with body shape via body shape questionnaire (BSQ), quality of life via WHOQoL-BREF, acceptance of weight related thoughts and feelings via acceptance and action questionnaire for weight-related difficulties (AAQ-W) at the end of the intervention which was 6–8 weeks	↓ EDE-Q ($p = 0.047$) ↓ SBEQ ($p = 0.006$) ↓ BSQ ($p = 0.023$) ↑ WHOQoL-BREF ($p = 0.022$) ↓ AAQ-W ($p = 0.006$)
Weineland et al.,[31] 2012 (follow up study)	A local centre for minimally invasive surgery	'Examine both the maintenance of behavioural change at a 6-month follow-up for the original study and the processes that may be involved in the outcomes'.	NR; Eating disordered behaviour via EDE-Q, binge eating via SBEQ, pre-occupation with body shape via BSQ, quality of life via WHOQoL-BREF, acceptance of weight related thoughts and feelings via AAQ-W at 6-month follow-up	↓ EDE-Q ($p = 0.067$). ≠ SBEQ ($p = 0.29$) ↓ BSQ ($p = 0.024$) ↑ WHOQoL-BREF ($p = 0.007$) ↓ AAQ-W ($p = 0.013$)
Wild et al.,[34] 2015 (initial study)	Three hospitals of which two were university hospitals	'The Bariatric Surgery and Education (BaSE) study aimed to assess the efficacy of a videoconferencing-based psychoeducational group intervention in patients after bariatric surgery.'	TWL (kg), health-related quality of life via SF-36 and self-efficacy via general self-efficacy scale (GSE) at 6 months and 12 months post-operatively.	≠ TWL (kg) at 6 months ($p = 0.92$) and 12 months ($p = 0.78$) ≠ SF-36 at 6 months ($p = 0.84$) and 12 months ($p = 0.39$) ≠ GSE at 6 months ($p = 0.66$) and 12 months ($p = 0.19$)

(Continues)

TABLE 3 (Continued)

Author, year	Setting	Study aim	Primary outcome(s)[a] and measure(s)	Intervention effect compared to control[b]
Wild et al.,[33] 2017 (follow up study)	Three hospitals of which two were university hospitals	'Evaluate the effects of the BaSE programme at longer-term follow-up.'	TWL (kg), health related quality of life via SF-36 and self-efficacy via GSE. The range of follow-up time was 23–61 months after surgery. This corresponds to a follow-up time of 11–49 months after the end of the intervention programme.	≠ TWL (kg) ($p = 0.82$) ≠ SF-36 ($p = 0.65$) ↑ GSE ($p = 0.03$)

Abbreviations: AAQ-W, action questionnaire for weight-related difficulties; BDI, Beck's depression inventory; BES, binge eating scale; BMI, body mass index; BSI, brief symptom inventory; BSQ, body shape questionnaire; DEBQ, Dutch eating behaviour questionnaire; EBI, eating behaviour inventory; EDE-Q, eating disorder examination questionnaire; EES emotional eating scale; EWL, excess weight loss; GSE, general self-efficacy scale; GSI, global severity index; HADS, hospital anxiety and depression scale; mYFAS 2.0, modified Yale Food Addiction Scale 2.0; NR, not reported; OBESE scale, Ontario bariatric eating self-efficacy; QIDS-SR, quick inventory of depressive symptomatology; SBEQ, subjective binge eating questionnaire; SF-36, 36-item short-form survey; SQUASH, short questionnaire to assess health-enhancing physical activity; TFEQ-R21, three-factor eating questionnaire; TWL, total weight loss; VAS, visual analogue scale; WHOQoL-BREF, World Health Organization quality of life assessment.

[a]Primary outcome(s) as stated in the study. If the study did not indicate the primary outcomes, they were based off the study aim.

[b]↑ or ↓ indicates the intervention significantly improved outcomes compared to control and ≠ indicates no significant change between the intervention and control.

[c]The control significantly improved weight loss at 24 months compared to intervention.

The 15 studies published across 21 reports were conducted in the USA ($n = 5$ studies),[21–27] Canada ($n = 3$ studies),[19,20,28] United Kingdom ($n = 1$ study),[29] Netherlands ($n = 1$ study),[30] Sweden ($n = 1$ study),[31,32] Germany ($n = 1$ study),[33,34] New Zealand ($n = 1$ study),[35] Norway ($n = 1$ study)[36–38] and Portugal ($n = 1$ study).[39] Samples comprised mostly mixed bariatric surgeries ($n = 7$ samples),[20,21,23,25,31–34,36–38] followed by Roux-en-Y gastric bypass ($n = 3$ samples),[22,24,26,27,29] waitlisted ($n = 2$ samples)[19,39] and gastric sleeve ($n = 1$ sample).[35] Two studies did not report surgery type.[28,30] The setting for most of the studies was a hospital ($n = 7$ studies).[20,28,29,33–39] Most interventions were delivered post-operatively ($n = 10$ interventions),[20,21,23–25,27,28,31–38] followed by pre-operatively ($n = 4$ interventions),[19,22,26,30,39] and both pre- and post-operatively ($n = 1$ intervention).[29] Interventions were delivered in-person ($n = 7$ interventions),[21,23,24,27–30,39] via telephone ($n = 1$ intervention),[19,20] text messages ($n = 1$ intervention)[35] or a combination of modalities ($n = 5$ interventions).[22,25,26,31–34,36–38] Additional characteristics can be seen in Table 2. The intervention and report aim varied in focus, some with multiple components (Table 3). This included aiming to achieve a change in weight ($n = 10$ reports),[21,22,24,25,29,30,35,36,38,39] eating behaviours and psychopathology ($n = 7$ reports),[19,20,25,28,32,36,38] psychosocial variables ($n = 3$ reports),[19,30,39] anxiety and depression screening ($n = 2$ reports),[27,37] quality of life ($n = 2$ reports),[32,36] self-efficacy ($n = 1$ report)[28] and diet ($n = 1$ report).[25] Of the 21 included reports, over one third did not describe the primary outcome(s) of the study ($n = 8$ reports, 38%; Table 3).[20,22,26,28,30–32,38] Of those that did, weight status and metabolic control indicators were the most common ($n = 9$ reports),[24,25,27,29,33–35,38,39] followed by changes in eating psychopathology ($n = 4$ reports),[19,36–38] quality of life ($n = 3$ reports)[23,33,34] and anxiety and depression screening ($n = 2$ reports).[27,38]

Comparison groups included usual care ($n = 12$ studies),[19–23,25,26,29–38] minimal care ($n = 2$ studies)[24,27,39] and waitlist control ($n = 1$ study; Table 2).[28] Usual care was provided by a surgeon ($n = 1$ study),[33,34] dietitian ($n = 2$ studies),[21,25] surgeon, dietitian, nurse, doctor or physical therapist ($n = 3$ studies)[29,31,32,36–38] or was not detailed ($n = 6$ studies).[19,20,22,23,26,30,35]

Overall bias was low ($n = 8$ studies),[19,22,26,28–30,35–38] or had some concerns ($n = 7$ studies; Figure S1).[20,23–25,27,31–34,39] The risk of bias for 'selection of reported results', 'measurement of the outcome', 'missing outcome data' and 'deviations from intended interventions' were generally low. For the randomisation process, 47% of reports had some concerns ($n = 7$ studies).

Of the 14 interventions, the majority did not report using any behaviour change theories to inform the nutrition intervention ($n = 12$ interventions, 86%; Table 2).[19–27,29–38]

TABLE 4 Reported behaviour change theories and behaviour change techniques according to the behaviour change technique taxonomy (version one),[9] in intervention arms of the included interventions

	Interventions[a]														
Behaviour change theory or technique	**1**	**2**	**3**	**4**	**5**	**6[b]**	**7**	**8**	**9**	**10[c]**	**11**	**12**	**13**	**14**	**Total[d]**
Behaviour change theory															
Transtheoretical model	●			●											2
Self-determination theory	●														1
Behaviour change technique (no. Label)															
1.0 Goals and planning	●	●	●	●	●	●	●	●	●	●	●		○	●	12
1.1 Goal setting (behaviour)		●	●	●		●		●			●				6
1.2 Problem solving		●	●	○	●	●		●	●	●	●		○	●	9
1.4 Action planning		●	○					●					○		3
1.6 Discrepancy between current behaviour and goal	●							○							1
1.9 Commitment													●		1
2.0 Feedback and monitoring		●	●		○	●	●	●	●		●	●		●	9
2.1 Monitoring of behaviour by others without feedback					○			○				○			0
2.2 Feedback on behaviour					○	●									1
2.3 Self-monitoring of behaviour		●				●			●		●	●		●	6
2.4 Self-monitoring of outcomes of behaviour		●	●			●		●							4
3.0 Social support	○	●	●	●	●	●	●	●	●		●			●	10
3.1 Social support (unspecified)	○	●	●	●	●	●		●	●		●			●	9
3.2 Social support (practical)		●	●			●		●						●	5
3.3 Social support (emotional)		●						●	●						3
4.0 Shaping knowledge	○	●			○	●	●	●	●	○	●		○	○	6
4.1 Instruction on how to perform the behaviour		●				●			●						3
5.0 Natural consequences		○		●			●	●			○		○		3
5.1 Information about health consequences		○		●				●							2
7.0 Associations		●	○		●	●	●	○	●		○		●		6
7.1 Prompts and cues		●			●				●				●		4
7.5 Remove aversive stimulus		●				●									2
7.6 Satiation		○													0
8.0 Repetition and substitution	●	●	●		●	●	●	●	●		●		●	○	10
8.1 Behavioural practise and rehearsal			●		●	●		●			○		○	○	4
8.2 Behaviour substitution	●	●				●					●				4
8.3 Habit formation									○						0
8.7 Graded tasks						●			●				●		3
9.0 Comparison of outcomes		●		●							●				3
9.2 Pros and cons		●		●							●				3
10.0 Reward and threat							●								1
11.0 Regulation		●				●	●						●	●	5
11.2 Reduce negative emotions		●				●							●	●	4

(Continues)

TABLE 4 (Continued)

Behaviour change theory or technique	Interventions[a] 1	2	3	4	5	6[b]	7	8	9	10[c]	11	12	13	14	Total[d]
12.0 Antecedents					●		○	○							1
12.3 Avoidance/reducing exposure to cues for the behaviour					●										1
13.0 Identity		●		○		○	●				●		○		3
13.2 Framing/reframing		●				○					●		○		2
13.3 Incompatible beliefs				○											0
15.0 Self belief	●		●	●	○		●				○				4
15.2 Mental rehearsal of successful performance				●											1
15.3 Focus on past success	●		●	●	○										3
15.4 Self talk	○			○											0
Total no. of techniques used in each study[d]	6	24	12	11	10	20	12	15	13	2	14	2	7	9	

Note: Key = ● Objective coding ○ Subjective coding.

[a]Studies are numbered in alphabetical order: 1 = Camolas et al.,[39] 2 = Cassin et al., 2016 and Cassin et al., 2020,[19,20] 3 = Chacko et al.,[21] 4 = David et al.,[28] 5 = Gade et al., 2014, Gade et al., 2015 and Hjelmesaeth,[36–38] 6 = Kalarchian et al., 2013, and Kalarchian 2016,[22,26] 7 = Lauti et al.,[35] 8 = Lent et al.,[23] 9 = Nijamkin et al., 2012 and Nijamkin et al., 2013,[24,27] 10 = Ogden et al.,[29] 11 = Paul et al.,[30] 12 = Sarwer et al.,[25] 13 = Weineland et al., 2012(A) and Weineland et al., 2012(B),[31,32] 14 = Wild et al., 2015 and Wild et al., 2017,[33,34] (Note: While Cassin et al., 2016 and Cassin et al., 2020 are different in that one was delivered pre-operatively,[19] and the other post-operatively,[20] they both used the same intervention hence have been combined in this table).

[b]Obtained from a published book chapter,[53] as the intervention was only briefly described within the manuscript.

[c]Obtained from published protocol,[54] as behaviour change techniques were not detailed in the intervention within the manuscript.

[d]Total only include techniques that were determined through objective coding and does not include those coded subjectively.

Two interventions used the transtheoretical model[28,39] and self-determination theory.[39] Three interventions were based on cognitive behavioural therapy,[19,20,23,36–38] one on acceptance and commitment therapy[31,32] and one on motivational interviewing.[39]

Thirteen behaviour change technique taxonomy groupings and 29 techniques were reported across the 14 interventions (Table 4). The mean number of techniques was 11 and ranged from 2 to 24. The most common behaviour change technique taxonomy groupings were '1.0 Goals and planning' (n = 12 interventions), '3.0 Social support' (n = 10 interventions), '8.0 Repetition and substitution' (n = 10 interventions) and '2.0 Feedback and monitoring' (n = 9 interventions). The most common techniques were '1.2 Problem solving' (n = 9 interventions), '3.1 Social support (unspecified)' (n = 9 interventions), '1.1 Goal setting (behaviour)' (n = 6 interventions) and '2.3 Self-monitoring of behaviour' (n = 6 interventions; Table 4). Seven techniques were ambiguous and coded as 'unspecified'.

Three studies found significant improvements in the intervention group for weight loss (Table 3).[22,24,26,27,39] All three used techniques from the following behaviour change technique taxonomy groupings '1.0 Goals and planning', '4.0 Shaping knowledge' and '8.0 Repetition and substitution'; however, no technique was commonly used across all three studies. Three studies found significant improvement in the intervention group for binge eating.[19,28,32] The common behaviour change technique taxonomy grouping was '1.0 Goals and planning'; however, likewise, there were no common techniques used across all three studies.

Two studies were categorised as having both the intervention and control delivered by a credentialed nutrition or dietetics practitioner.[25,39] Camolas et al.[39] reported a significant intervention effect over the minimal care control (Table 3), including significant improvements in body mass index (p = 0.001), total weight loss percentage (p = 0.001), excess weight loss (p = 0.001) and fasting glycaemia (p = 0.019).[39] Sarwer et al.[25] reported no significant difference in total weight loss percentage (p = 0.08) compared to usual care. Intervention effect was observed in studies where the intervention implemented cognitive behavioural therapy,[19,20,23,38] motivational interviewing,[28] acceptance and commitment therapy[31,32] and psychoeducation (Table 3).[33,34]

4 | DISCUSSION

The findings from this review suggest behaviour change theory is not consistently reported and/or adopted to inform nutrition interventions for adults undergoing

bariatric surgery. The use of theory was limited to two studies using the transtheoretical model and self-determination theory. Behaviour change techniques were more widely incorporated with the most common including '1.2 Problem solving', '3.1 Social support (unspecified)', '1.1 Goal setting (behaviour)' and '2.3 Self-monitoring of behaviour'. The impact of integrating behaviour change theory and techniques in interventions, on patient outcomes, was not determined.

The absence of behaviour change theory reported and/or adopted to inform nutrition interventions for adults undergoing bariatric surgery highlights a potential disparity between intervention settings and populations. A recent review by Rigby et al.[40] found all of the dietary interventions delivered by qualified dietitians in various primary health care settings were underpinned by behaviour change theories. The intervention aims of included studies reported by Rigby et al.[40] included achieving change in weight, diet or clinical conditions. Comparatively, in the current review, aims varied including achieving change in weight, eating behaviours and psychopathology, psychosocial variables, anxiety and depression screening, quality of life, self-efficacy and diet. Applying behaviour change theories to interventions for adults undergoing bariatric surgery may be particularly challenging due to the need to target multiple behaviours. It may be necessary to integrate hypotheses from multiple behaviour change theories to overcome this challenge; referred to as an 'integrated behaviour change model'.[41] Literature regarding the application of integrated behaviour change models on dietary behaviours is limited yet emerging,[42–45] and exploration of the applicability to adults undergoing bariatric surgery is warranted. This is particularly important given Rigby et al.[40] found dietary interventions based on behaviour change theory and techniques were potentially more effective at improving patient health outcomes than interventions without theoretical underpinnings. While behaviour change science is valued by the dietetic profession,[46] we encourage embedding and documenting behaviour change theory in dietetic practice to improve patient-centred care.

The most commonly reported behaviour change techniques identified were '1.2 Problem solving', '3.1 Social support (unspecified)', '1.1 Goal setting (behaviour)' and '2.3 Self-monitoring of behaviour'. Results are consistent with other reviews exploring diet and physical activity interventions,[16,40] weight loss and weight maintenance eHealth interventions[47] and eHealth interventions for adults undergoing bariatric surgery.[48] However, knowing the common behaviour change techniques does not help to determine which techniques to select. Johnston et al. have hypothesised links between behaviour change techniques and mechanisms of action and subsequently created an online interactive tool.[49] This tool may assist clinicians and interventionalists to select techniques for inclusion in intervention design based on evidence. The common behaviour change techniques identified in our review link to the following mechanisms of action: 'beliefs about capabilities', 'behaviour regulation', 'social influences', 'intention', 'goals' and 'feedback processes'. Through making an appraisal of these links, key techniques may become apparent. For example, the technique '11.2 Reduce negative emotions' links to the mechanism of action 'emotion' which may be beneficial for those displaying emotional eating. The authors encourage the bariatric surgery care team, including dietitians, to reflect on patients' modifiable determinants and the behavioural predictors of weight regain after bariatric surgery. In addition, the authors encourage codesigning interventions and taking a collaborative approach with patients after bariatric surgery to foster participatory practice.

Objective and subjective coding of techniques was a novel approach; previous reviews have only coded objectively with the limitation that techniques may be under-reported.[40,48] This was required due to the complex and interacting components of interventions and to gain a robust insight regarding all techniques applied in the body of literature. The authors recommend researchers place their efforts on reporting intervention components as per the behaviour change technique taxonomy to assist in strengthening intervention replication and implementation.[50] In addition, this may also help with future synthesis to determine if certain behaviour change techniques are more effective than others. This extends to other emerging areas of nutrition intervention, such as eHealth[51]; as half of the interventions in the included studies utilised eHealth modalities.

This review has limitations worth noting. The authors cannot exclusively say nutrition interventions for adults scheduled for (waitlisted) or who have undergone bariatric surgery are not explicitly informed by one or more behaviour change theories; rather publications are not reporting the use of theory. While comparison groups that were informed by behaviour change theories were excluded, behaviour change theory and techniques may be implemented as part of usual nutrition care without being documented. While the inclusion of randomised control trials aimed to provide the most robust level of research, including other study designs may have provided greater insight into theory-informed interventions. With substantial heterogeneity, the authors were unable to evaluate the effectiveness of the inclusion of behaviour change theory or techniques on health behaviours or outcomes. Results do not indicate that common behaviour change techniques lead to effective outcomes. The risk of bias for outcome measures does not assess the methodology of coding behaviour change techniques, hence caution should be taken when

interpreting this risk of bias. While the objective and subjective coding of behaviour change techniques is a novel approach, subjective coding is subject to bias. Furthermore, authors subjectively coded to 'groupings' which required creating criteria, a process that is also subject to bias.

This systematic review highlights that while behaviour change techniques have been included, behaviour change theory is not consistently reported and/or adopted to inform nutrition interventions for adults undergoing bariatric surgery. Behaviour change theories used included the transtheoretical model and self-determination theory. Common behaviour change techniques included '1.2 Problem solving', '3.1 Social support (unspecified)', '1.1 Goal setting (behaviour)' and '2.3 Self-monitoring of behaviour'. Integrating behaviour change theory and techniques in nutrition interventions is important for researchers and bariatric surgery teams, including dietitians, to effectively target behaviours.

CONFLICT OF INTEREST

Katrina Campbell is a member of the Journal Strategic Planning Committee of Nutrition & Dietetics. They were excluded from the peer review process and all decision-making regarding this article. This manuscript has been managed throughout the review process by the Journal's Editor-in-Chief. The Journal operates a blinded peer review process and the peer reviewers for this manuscript were unaware of the authors of the manuscript. This process prevents authors who also hold an editorial role to influence the editorial decisions made.

AUTHOR CONTRIBUTIONS

CW is responsible for ensuring that the descriptions are accurate and agreed by all authors. Conceptualisation: CW; Methodology: CW, KH; Literature Search: CW; Literature Evaluation: CW, AB; Data Extraction: CW, AB, KH; Writing – first draft: CW, JK; Writing – review and editing: JK, KC, KH; Supervision: JK, KC, KH.

DATA AVAILABILITY STATEMENT

Data extracted from included studies is available in the manuscript or supplementary materials

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REFERENCES

1. Colquitt JL, Pickett K, Loveman E, Frampton GK. Surgery for weight loss in adults. *Cochrane Database Syst Rev*. 2014;8:Cd003641.
2. Australian Institute of Health and Welfare. *Weight Loss Surgery in Australia 2014–15: Australian Hospital Statistics*. Australian Government; 2017.
3. Australian Institute of Health and Welfare. *Weight Loss Surgery in Australia 2018–19: Australian Hospital Statistics*. Australian Government; 2019.
4. Dietitians Australia. Bariatric Surgery Role Statement 2017.
5. National Health Medical Research Council. *Clinical Practice Guidelines for the Management of Overweight and Obesity in Adults, Adolescents and Children in Australia*. Australian Government Department of Health; 2013.
6. Odom J, Zalesin KC, Washington TL, et al. Behavioral predictors of weight regain after bariatric surgery. *Obes Surg*. 2010;20(3):349-356.
7. Athanasiadis DI, Martin A, Kapsampelis P, Monfared S, Stefanidis D. Factors associated with weight regain post-bariatric surgery: a systematic review. *Surg Endosc*. 2021;35(8):4069-4084.
8. Hagger MS, Cameron LD, Hamilton K, Hankonen N, Lintunen T. Changing behavior: a theory and evidence-based approach. *The Handbook of Behavior Change*. Cambridge University Press; 2020.
9. Michie S, Richardson M, Johnston M, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Ann Behav Med*. 2013;46(1):81-95.
10. Kok G, Gottlieb NH, Peters G-JY, et al. A taxonomy of behaviour change methods: an intervention mapping approach. *Health Psychol Rev*. 2016;10(3):297-312.
11. Green L, Kreuter M. The precede–proceed model. *Health Promotion Planning: an Educational Approach*. 3rd ed. *Mayfield Publishing Company*; 1999:32-43.
12. Michie S, Van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implementation Sci*. 2011;6(1):1-12.
13. Page MJ, McKenzie JE, Bossuyt PM, et al. Statement: an updated guideline for reporting systematic reviews. *BMJ*. 2020;2021:n71.
14. Clark JM, Sanders S, Carter M, et al. Improving the translation of search strategies using the polyglot search translator: a randomized controlled trial. *J Med Library Assoc*. 2020;108(2):195-207.
15. Michie S, West R, Campbell R, Brown J, Gainforth H. *ABC of behaviour change theories*. Silverback Publishing; 2014.
16. Cradock KA, ÓLaighin G, Finucane FM, Gainforth HL, Quinlan LR, Ginis KA. Behaviour change techniques targeting both diet and physical activity in type 2 diabetes: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2017;14(1):18.
17. Silver C, Lewins A. *Using software in qualitative research: a step-by-step guide*. Sage; 2014.
18. Higgins JP, Thomas J, Chandler J, et al. *Cochrane Handbook for Systematic Reviews of Interventions*. John Wiley & Sons; 2019.

19. Cassin SE, Sockalingam S, Du C, Wnuk S, Hawa R, Parikh SV. A pilot randomized controlled trial of telephone-based cognitive behavioural therapy for preoperative bariatric surgery patients. *Behav Res Ther*. 2016;80:17-22.
20. Cassin S, Leung S, Hawa R, Wnuk S, Jackson T, Sockalingam S. Food addiction is associated with binge eating and psychiatric distress among post-operative bariatric surgery patients and may improve in response to cognitive behavioural therapy. *Nutrients*. 2020;12(10):2905.
21. Chacko SA, Yeh GY, Davis RB, Wee CC. A mindfulness-based intervention to control weight after bariatric surgery: preliminary results from a randomized controlled pilot trial. *Complement Ther Med*. 2016;28:13-21.
22. Kalarchian MA, Marcus MD, Courcoulas AP, Cheng Y, Levine MD. Preoperative lifestyle intervention in bariatric surgery: a randomized clinical trial. *Surg Obes Related Dis*. 2016;12(1):180-187.
23. Lent MR, Campbell LK, Kelly MC, et al. The feasibility of a behavioral group intervention after weight-loss surgery: a randomized pilot trial. *PLoS One*. 2019;14(10):e0223885.
24. Nijamkin MP, Campa A, Sosa J, Baum M, Himburg S, Johnson P. Comprehensive nutrition and lifestyle education improves weight loss and physical activity in Hispanic Americans following gastric bypass surgery: a randomized controlled trial. *J Acad Nutr Diet*. 2012;112(3):382-390.
25. Sarwer DB, Moore RH, Spitzer JC, Wadden TA, Raper SE, Williams NN. A pilot study investigating the efficacy of postoperative dietary counseling to improve outcomes after bariatric surgery. *Surg Obes Related Dis*. 2012;8(5):561-568.
26. Kalarchian M, Marcus M, Courcoulas A, Cheng Y, Levine M. Preoperative lifestyle intervention in bariatric surgery: initial results from a randomized, controlled trial. *J Obes*. 2013;21(2):254-260.
27. Nijamkin M, Campa A, Samiri Nijamkin S, Sosa J. Comprehensive behavioral-motivational nutrition education improves depressive symptoms following bariatric surgery: a randomized, controlled trial of obese Hispanic Americans. *J Nutr Educ Behav*. 2013;45(6):620-626.
28. David LA, Sockalingam S, Wnuk S, Cassin SE. A pilot randomized controlled trial examining the feasibility, acceptability, and efficacy of adapted motivational interviewing for postoperative bariatric surgery patients. *Eat Behav*. 2016;22:87-92.
29. Ogden J, Hollywood A, Pring C. The impact of psychological support on weight loss post weight loss surgery: a randomised control trial. *Obes Surg*. 2015;25(3):500-505.
30. Paul L, van der Heiden C, van Hoeken D, et al. Cognitive behavioral therapy versus usual care before bariatric surgery: one-year follow-up results of a randomized controlled trial. *Obes Surg*. 2021;31(3):970-979.
31. Weineland S, Hayes SC, Dahl J. Psychological flexibility and the gains of acceptance-based treatment for post-bariatric surgery: six-month follow-up and a test of the underlying model. *Clin Obes*. 2012;2(1–2):15-24.
32. Weineland S, Arvidsson D, Kakoulidis TP, Dahl J. Acceptance and commitment therapy for bariatric surgery patients, a pilot RCT. *Obes Res Clin Pract*. 2012;6(1):e1-e90.
33. Wild B, Hünnemeyer K, Sauer H, et al. Sustained effects of a psychoeducational group intervention following bariatric surgery: follow-up of the randomized controlled BaSE study. *Surg Obes Related Dis*. 2017;13(9):1612-1618.
34. Wild B, Hünnemeyer K, Sauer H, et al. A 1-year videoconferencing-based psychoeducational group intervention following bariatric surgery: results of a randomized controlled study. *Surg Obes Related Dis*. 2015;11(6):1349-1360.
35. Lauti M, Kularatna M, Pillai A, Hill AG, MacCormick AD. A randomised trial of text message support for reducing weight regain following sleeve gastrectomy. *Obes Surg*. 2018;28(8):2178-2186.
36. Hjelmesæth J, Rosenvinge JH, Gade H, Friborg O. Effects of cognitive behavioral therapy on eating behaviors, affective symptoms, and weight loss after bariatric surgery: a randomized clinical trial. *Obes Surg*. 2019;29(1):61-69.
37. Gade H, Hjelmesæth J, Rosenvinge JH, Friborg O. Effectiveness of a cognitive behavioral therapy for dysfunctional eating among patients admitted for bariatric surgery: a randomized controlled trial. *J Obes* 2014;2014:127936, 1, 6.
38. Gade H, Friborg O, Rosenvinge JH, Småstuen MC, Hjelmesæth J. The impact of a preoperative cognitive Behavioural therapy (CBT) on dysfunctional eating Behaviours, affective symptoms and body weight 1 year after bariatric surgery: a randomised controlled trial. *Obes Surg*. 2015;25(11):2112-2119.
39. Camolas J, Santos O, Moreira P, do Carmo I. INDIVIDUO: results from a patient-centered lifestyle intervention for obesity surgery candidates. *Obes Res Clin Pract*. 2017;11(4):475-488.
40. Rigby RR, Mitchell LJ, Hamilton K, Williams LT. The use of behavior change theories in dietetics practice in primary health care: a systematic review of randomized controlled trials. *J Acad Nutr Diet*. 2020;120(7):1172-1197.
41. Hagger MS, Hamilton K. Changing behaviour using integrated theories. *The Handbook of Behavior Change*. Cambridge University Press; 2020.
42. Hagger MS, Chatzisarantis NLD. An integrated behavior change model for physical activity. *Exerc Sport Sci Rev*. 2014;42(2):62-69.
43. Brown D, Hagger M, Morrissey S, Hamilton K. Predicting fruit and vegetable consumption in long-haul heavy goods vehicle drivers: application of a multi-theory, dual-phase model and the contribution of past behaviour. *Appetite*. 2018;121:326-336.
44. Zhang C-Q, Wong MC-Y, Zhang R, Hamilton K, Hagger MS. Adolescent sugar-sweetened beverage consumption: an extended health action process approach. *Appetite*. 2019;141:104332.
45. Hagger MS, Trost N, Keech JJ, Chan DK, Hamilton K. Predicting sugar consumption: application of an integrated dual-process, dual-phase model. *Appetite*. 2017;116:147-156.
46. Rigby RR, Williams LT, Ball L, Hamilton K, Mitchell L. Is there enough behaviour change science in nutrition and dietetics curricula in Australia and New Zealand? A descriptive study. *Nutr Diet*. 2021;1-11.
47. Asbjørnsen RA, Smedsrød ML, Nes LS, et al. Persuasive system design principles and behavior change techniques to stimulate motivation and adherence in electronic health interventions to support weight loss maintenance: scoping review. *J Med Internet Res*. 2019;21(6):e14265.
48. Wright C, Mutsekewa R, Hamilton K, Campbell K, Kelly J. Are eHealth interventions for adults who are scheduled for or have undergone bariatric surgery as effective as usual care? A systematic review. *Surg Obes Related Dis*. 2021;17:2065-2080.

49. Johnston M, Carey RN, Connell Bohlen LE, et al. Development of an online tool for linking behavior change techniques and mechanisms of action based on triangulation of findings from literature synthesis and expert consensus. *Transl Behav Med*. 2021;11(5):1049-1065.
50. Boutron I, Moher D, Altman DG, Schulz KF, Ravaud P. Extending the CONSORT statement to randomized trials of nonpharmacologic treatment: explanation and elaboration. *Ann Intern Med*. 2008;148(4):295-309.
51. Kelly J, Collins P, McCamley J, Ball L, Roberts S, Campbell K. Digital disruption of dietetics: are we ready? *J Hum Nutr Diet*. 2021;34(1):134-146.
52. Cane J, Richardson M, Johnston M, Ladha R, Michie S. From lists of behaviour change techniques (BCTs) to structured hierarchies: comparison of two methods of developing a hierarchy of BCTs. *Br J Health Psychol*. 2015;20(1):130-150.
53. Mitchell JE, De Zwaan M. *Psychosocial Assessment and Treatment of Bariatric Surgery Patients*. Taylor & Francis; 2012.
54. Hollywood A, Ogden J, Pring C. The impact of a bariatric rehabilitation service on weight loss and psychological adjustment-study protocol. *J BMC Public Health*. 2012;12(1):1-5.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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